NOTICE

All drawings located at the end of the document.

Final
Phase III RFI/RI

Rocky Flats Plant
881 Hillside Area
(Operable Unit No. 1)

June 1994

EXECUTIVE SUMMARY

This report presents the results for the Resource Conservation and Recovery Act Facility Investigation/Comprehensive Environmental Response, Compensation, and Liability Act Remedial Investigation (RFI/RI) of the 881 Hillside Area Operable Unit No. 1 (OU1) at the Rocky Flats Plant (RFP). The objectives of the Phase III RFI/RI are: 1) to characterize surficial and subsurface physical features at the OU; 2) to identify the site contaminants; 3) to characterize contaminant sources and the nature and extent of contamination at the site; and 4) to provide a baseline risk assessment that considers contaminant fate and transport and assesses the threat to public health and the environment from a no-action remedial alternative. Additionally, the RFI/RI is to provide and develop data needed for feasibility studies of remedial alternatives as appropriate.

The 881 Hillside Area was originally identified as a high priority area due to high concentrations of volatile organic compounds (VOCs) detected in groundwater and to the proximity of the 881 Hillside Area to Woman Creek. In addition, concentrations of trace metals, radionuclides (RADs), and some semivolatile organic compounds (SVOCs) above RFP background values were considered to be the result of possible contamination from past plant processes or fallout of airborne pollution.

Geologic units present at the 881 Hillside Area includes Rocky Flats Alluvium at the top of the hillside, colluvium and fill along central portions of the hillside, and Woman Creek Valley Fill Alluvium at the base. These thin surficial units are underlain by thick Cretaceous claystone, siltstone, and sandstone of the Laramie Formation. The upper portion (25 feet) of the Laramie Formation is disturbed as a result of slumping on the hillside and also contains numerous fractures.

Groundwater occurs in the unconsolidated materials, disturbed bedrock, and in the deeper coarse beds within the Laramie Formation. Groundwater in the saturated unconsolidated materials and the upper 25 feet of Laramie Formation occurs under unconfined conditions. This interval is designated as the Upper Hydrostratigraphic Unit (UHSU). Groundwater occurring in the coarser beds within the Laramie Formation at depths exceeding 25 feet below the bedrock contact can occur under confined or unconfined conditions. This interval is designated as the Lower Hydrostratigraphic Unit (LHSU).

UHSU groundwater is not present across the entire Operable Unit. Groundwater in the unconsolidated materials typically is confined to north-south tending erosional incisions in the bedrock surface described as paleochannels in the body of the Report. The extent of groundwater within these paleochannels varies with seasonal changes in precipitation rates. UHSU groundwater also occurs sporadically within the upper portion of the Laramie Formation within fractures and along slump block glide planes.

During 1991 and 1992, a French Drain was installed midway between the top of the hillside and Woman Creek to intercept shallow groundwater. Based on limited water level data collected since its installation, the French Drain appears to be functioning as a hydraulic barrier to the migration of UHSU groundwater. The French Drain extends to a maximum depth of 28 feet below the top of bedrock and, based on direct observations during construction, extends below the maximum depth of saturated fractures and slump block glide planes.

The interaction between the UHSU and LHSU is limited by the typically low vertical hydraulic conductivity of the Laramie Formation claystones. The actual rate of recharge of UHSU groundwater to the LHSU has not been quantified. However, the typical vertical hydraulic conductivity of the Laramie claystones (1E-8 centimeters per second [cm/sec]) is approximately three orders of magnitude lower than the horizontal hydraulic conductivity of the unconsolidated sediments (1E-5 cm/sec). This suggests that, although vertical migration of UHSU groundwater to the LHSU is possible, the rate of migration is small compared with the rate of horizontal migration.

A detailed methodology was developed for determining contaminants at OU1. This methodology involved the use of many "tools" including statistical comparisons to background concentrations, examination of spatial and temporal concentration distributions at OU1, and evaluation of the potential for laboratory or field-introduced sample contamination. Using this methodology, analytes within the chemical classes VOCs, SVOCs, pesticides/polychlorinated biphenyls (PCBs), metals, and RADs were determined to be OU1 contaminants. None of these contaminants are present in every medium. As expected, based on historical waste management practices, chlorinated solvents (VOCs) and RADs are contaminants at OU1. Unexpected contaminants at OU1 are selenium and vanadium in groundwater, and polynuclear aromatic hydrocarbons (PAHs) and PCBs in surface soils. It is possible that the selenium and vanadium are naturally occurring, but their high concentrations and the lack of sufficient data to conclusively prove their natural occurrence have resulted in selenium and vanadium being retained as groundwater contaminants. The PAHs occur throughout OU1 including areas outside Individual Hazardous Substance Sites (IHSSs) (Figure F2-13). Their distribution in surface soils is not indicative of contamination originating from an OU1 waste source. Nevertheless, their absence in background surface soils and frequent occurrence in surface soils at OU1 indicate they are contaminants at OU1. Although asphalt disposed at IHSS 130 may account for some of the PAHs detected in subsurface soils, the fact that these wastes are buried suggests they are not the source for PAHs distributed across OU1. The PCB contamination is localized and occurs at low levels. Because PCB contamination exists elsewhere at RFP, it is not possible to definitively conclude that PCBs are not contaminants at OU1.

The results of the RFI/RI have identified three general areas within OU1 contaminated by VOCs (Figures F2-9 and F2-10). These general areas of contamination include the Building 881 area, the area in and downgradient of IHSS 119.1, and the area in and downgradient of IHSS 119.2. Based on media-specific chemical data, the previously described hydrogeologic model, and historical contaminant storage and release information, at least one discrete source area has been identified or postulated for the three general areas of contamination. In the Building 881 area, a release of an aqueous solution of VOCs originating from a sanitary sewer line is presumed to be at least partially responsible for a diffuse VOC groundwater plume in that area. VOC (and RAD [uranium/americium and plutonium]) releases from drums stored within IHSS 119.1 are considered to be the source for a VOC groundwater plume in this area (and for localized occurrences of elevated RADs in soils, i.e., hot spots, within the IHSS). VOC releases originating within waste storage at IHSS 119.2 coupled with VOC releases at the 903 Pad (Operable Unit No. 2) upgradient of IHSS 119.2 are believed to account for VOCs detected in groundwater downgradient of IHSS 119.2.

Releases of VOCs within IHSS 119.1 appear to have occurred in the form of dense, nonaqueous phase liquids (DNAPLs). This conclusion is based on the historical storage of waste solvents and other hydrocarbons at this IHSS coupled with the presence of chlorinated solvents concentrations in groundwater representing as much as 7% of the substance solubility limit. The presence of mobile or immobile (residual) DNAPL at this location is inferred as DNAPL has not been directly observed or measured at OU1. The observed occurrence of VOCs in subsurface soils is limited to detections of less than 2.0 milligrams per kilogram (mg/kg).

Metal contaminants in groundwater (selenium and vanadium) generally were found to co-occur with the VOCs at concentrations roughly proportional to the concentration of VOCs (Figure F2-12). This is a general trend and exceptions exist. The origin of these metals is not certain as are documented RFP wastes. Three possible origins are postulated including: 1) undocumented selenium- and vanadium-containing RFP wastes; 2) undocumented RFP wastes with chelating or strong acid/base properties that might have mobilized the metals from native soils or; 3) naturally occurring selenium- and/or vanadium-bearing minerals.

The extent of groundwater contamination (VOCs and metals) is limited (with few exceptions) to areas north of the South Interceptor Ditch (roughly 1/2 the distance between the inferred source areas and Woman Creek). One exception to this generalization is the occurrence of trace levels of VOCs in Woman Creek Valley Fill Alluvial groundwater in the eastern portion of OU1. The data suggest these occurrences may be attributed to the combined effects of VOC releases at IHSS 119.2 and the 903 Pad (Operable Unit No. 2).

The occurrence of contaminants in LHSU groundwater is limited to relatively low levels of VOCs, typically less the 100 $\mu g/\ell$, and localized occurrences of metals, particularly selenium, in concentrations ranging from below background to 15 times the background value of 80 $\mu g/\ell$.

The observed extent of groundwater contamination originating from IHSS 119.1 was compared with the predicted extent to confirm the accuracy of the hydrogeologic conceptual model. Contaminant transport rates were estimated by calculating the groundwater seepage velocity and contaminant-specific retardation factors. The observed migration distance of VOC and metal contamination originating from IHSS 119.1 (approximately 300 feet) falls within the predicted range.

A similar exercise was performed to estimate the vertical migration rate of contaminants in groundwater using measured permeability values that range over four orders of magnitude. Agreement between the observed extent of vertical migration and predicted extent was only achieved using the extreme high end of the measured range of permeability. Because this permeability is not typical of the other measured values, the concept of vertical contaminant migration from the UHSU to the LHSU is not fully supported by this analysis. The presence of macroscopic secondary porosity (fractures), cross-contamination during drilling or cross-contamination after well construction may explain the presence of LHSU contamination.

In general, surface soils throughout OU1 are contaminated with windblown plutonium and americium transported from the 903 Pad Area (Figure F2-14). In addition, isolated "hot spots" of plutonium, americium, and uranium have been identified within IHSS 119.1 boundaries. These "hot spots" are associated with historical waste management activities at this IHSS, and appear to be a result of leaking drums of RAD-contaminated fluids. Surface soils in the eastern part of OU1 are contaminated with windblown PAHs presumed to originate from road dust, vehicle exhausts, and other combustion sources. PCB contamination has also been identified in surface and near-surface soils in the vicinity of IHSSs 119.1 and 119.2. With few exceptions, the widespread elevated levels of RADs and PAHs were confined to the near surface and, in most cases, in the upper few inches of soils. "Hot spot" RAD contamination appeared to be confined to the upper few feet of soil.

In general, contaminant migration at the site was evaluated in terms of the identified pathways at OU1. Migration of VOCs and metals in groundwater at IHSS 119.1 is restricted to north-south oriented channel features incised on the bedrock surface. However, based on available water level data, the operation of the French Drain appears to interrupt these pathways south of Building 881 and IHSS 119.1. In the eastern part of OU1, groundwater has the potential to migrate uninterrupted to Woman Creek; however, the contaminant concentrations in groundwater in this area are very low relative to those at IHSS 119.1, and there is no convincing evidence of actual contaminant migration to Woman Creek groundwater.

SVOCs in subsurface soils are expected to decrease in concentration with time due to natural degradation processes. These SVOCs have a low potential for migration and should remain confined to subsurface soils. Metals and RADs in subsurface soils are also expected to remain immobilized *in situ* by natural geochemical processes. RADs and SVOCs in surface soils are susceptible to redistribution by wind or surface water erosion events.

The Public Health Evaluation (PHE) developed a quantitative description and assessment of the risk to public health posed by the contaminants of concern (COCs) at OU1. The COC identification method uses a medium-specific concentration-toxicity screen that was agreed to by the Colorado Department of Health, U.S. Department of Energy, and U.S. Environmental Protection Agency at comment resolution meetings. Application of the screening process yields 20 OU1 COCs including VOCs, metals, PAHs and RADs.

Risks were assessed for ten exposure scenarios, including two current exposure scenarios, four future scenarios, and four special cases of one of the future scenarios. Of the four special case scenarios, three assume exposure to groundwater, and the fourth assumes that the predominant groundwater source (IHSS 119.1) and the RAD hot spots have been removed (Table ES-1).

For the two current exposure scenarios evaluated (off-site resident and on-site worker), calculated carcinogenic risks range from 2E-06 to 1E-04. These risks are within the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) target risk range of 1E-06 to 1E-04. Hazard indices have a calculated range of 1E-07 to 8E-05, well below the NCP target maximum of unity for both scenarios.

For three of the four future exposure scenarios evaluated (on-site office worker, on-site ecological researcher, and on-site resident [no groundwater exposure]), calculated carcinogenic risks range from 3E-03 to 4E-03, above the NCP target risk range. These risks are dominated by the inhalation of airborne particulate RADs and by inhalation of organics volatilized through the foundation into hypothetical buildings. Risks for the on-site construction worker is 4E-07, which is below the NCP range. The calculated range of noncarcinogenic impacts is from 1E-04 to 2E-02, below the NCP target of unit for all four scenarios.

For three of the four additional cases of future on-site resident scenarios evaluated (assuming exposure to contaminated groundwater to varying degrees), carcinogenic risk is calculated to range from 6E-03 to 7E-02, and is dominated by inhalation of airborne particulate RADs and exposure to groundwater. OU-wide risk with the source removed is calculated to be 5E-05, dominated by the ingestion of PAHs. The noncarcinogenic impacts are calculated to be above the NCP target of unity for the three scenarios involving exposure at the source, with values ranging from 9E+00 to 3E+02. These noncarcinogenic risks are dominated by exposure to organic compounds in groundwater. OU-wide hazard indices within the source removed are 7E-03 and 3E-03, below the NCP target minimum of unity.

It should be noted that the risk estimates for RADs (Class A carcinogens) for the first nine scenarios included the hot spot data using a simple average. This simple average was used to be consistent with inclusion of the groundwater source (IHSS 119.1) data in the groundwater data set. Due to the localized nature of the hot spots, use of an area-weighted average would provide more representative estimates of RAD risks that may be three orders of magnitude lower.

There are many other unquantified uncertainties, including the degree of confidence that residential use of the site would ever be permitted. Therefore, the impacts calculated under the on-site residential land use scenario are conservative; actual exposure, even under plausible future use scenarios, is expected to be lower.

The overall goals of the Environmental Evaluation (EE) were to ascertain whether contamination at OU1 may have impacted or could adversely impact ecological receptors in the immediate vicinity. It was determined that the concentrations of VOCs in groundwater, and PAHs and PCBs in soils are potentially toxic to ecological receptors. However, the restricted distribution of these contaminants limits the duration and frequency of contact with receptors and, therefore, limits exposure. The plant community in the OU1 IHSS area appears to have been impacted primarily through physical disturbance and revegetation efforts. If allowed, disturbed areas can probably regenerate through natural processes. Areas adjacent to OU1, but outside the disturbed sites, support a native and diverse biological community, which includes several sensitive and/or protected species. Exposure estimations suggest that while some contaminants occur at potentially toxic levels, the contaminated areas are not large enough to result in a significant threat to the populations of plants or animals in the Woman Creek drainage.

Table ES-1

Summary of OU1 Point Estimates of Risk

Scenario	Total Risk (Carcinogenic Classes)				Total Hazard Index	
	A	B2	C	Total	Child	Adult
Current						
On-Site Worker (Security Specialist)	1E-04*	6E-07	N/A	1E-04	N/A	8E-05
Off-Site Resident (Adult)	2E-06*	7E-10	N/A	2E-06	1E-07	6E-08
Standard Future						
Future On-Site Worker (Office)	2E-03*	2E-05	2E-04	2E-03	N/A	3E-03
Future On-Site Worker (Construction)	5E-09	2E-08	4E-07	4E-07	N/A	1E-04
On-Site Ecological Researcher	2E-03*	9E-06	N/A	2E-03	N/A	2E-03
On-Site Resident (Adult)	3E-03*	4E-05	2E-04	3E-03	2E-02	5E-03
Other Future						
On-Site Resident (Adult) (Sitewide With Groundwater)	3E-03*	3E-04	3E-03	6E-03	2E+01	9E+00
On-Site Resident (Adult) (Assuming Adequate Groundwater At Source)	3E-02*	4E-03	4E-02	7E-02	3E+02	1E+02
On-Site Resident (Adult) (Groundwater At Source With Public Water)	3E-02*	5E-04	6E-03	4E-02	3E+01	1E+01
On-Site Resident (Adult) (Without Source / Without Groundwater)	2E-05	3E-05	8E-07	5E-05	7E-03	3E-03

* Risk estimates for radionuclides include hot spot data using a simple average and are overestimated.

Carcinogenic Classes:

A = Human carcinogen

B2 = Probable human carcinogen

C = Possible human carcinogen

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LIST OF ACRONYMS AND ABBREVIATIONS

af	acre-feet
ANOVA	analysis of variance
ARARs	applicable or relevant and appropriate requirements
ATP	ambient temperature and pressure
BCF	biocentration factor
BRA	Baseline Risk Assessment
CDH	State of Colorado Department of Health
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
CLP	contract laboratory program
cm	centimeter
cm/sec	centimeters per second
CRDL	contract required detection limit
DNAPL	dense, nonaqueous phase liquid
DOE	Department of Energy
DQO	data quality objectives
DRCOG	Denver Regional Council of Governments
EDD	electronic data deliverable
EE	Environmental Evaluation
EEW	Environmental Evaluation Work Plan
EMD	Environmental Management Department
EPA	Environmental Protection Agency
ft^3/min	cubic feet per minute
FGSS	field gamma spectroscopy system
FIDLER	field instrument for the detection of low energy radiation
FS	feasibility study
FSP	Field Sampling Plan
g/cc	grams per cubic centimeter
GC/MS	gas chromatography/mass spectroscopy
gpd/ft	gallons per day per foot
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
HEAST	Health Effects Assessment Summary Table
HPGe	high purity germanium
HQ	Hazard Quotient
HRR	Historical Release Report
HSU	hydrostratigraphic unit
i.d.	inside diameter
IDL	instrument detection limit
IHSS	Individual Hazardous Substance Site
IM/IRA	interim measure/interim remedial action
IRIS	integrated risk information system

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

LCS	Laboratory Control Sample
LHSU	lower hydrostratigraphic unit
mg/kg	milligrams per kilogram
mg/ℓ	milligrams per liter
mm Hg	millimeters of mercury
m^2/g	square meters per gram
MS	matrix spike
MSA	method of standard additions
MSD	matrix spike duplicate
nCi/g	nanoCuries per gram
o.d.	outside diameter
OU1	Operable Unit No. 1
OU2	Operable Unit No. 2
OU5	Operable Unit No. 5
OU10	Operable Unit No. 10
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
pCi/g	picocuries per gram
pCi/ℓ	picocuries per liter
pCi/m^3	picocuries per cubic meter
pCi/mℓ	picocuries per milliliter
PGSS	portable gamma spectroscopy system
PHE	Public Health Evaluation
QA/QC	quality assurance/quality control
QRS	qualitative radiological survey
RAD	radionuclide
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RFEDS	Rocky Flats Environmental Database System
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFP	Rocky Flats Plant
RI	remedial investigation
RPD	relative percent difference
RRU	relative response unit
SARA	Superfund Amendments and Reauthorization Act
SID	South Interceptor Ditch
SOP	Standard Operating Procedure
SOW	statement of work
SVOC	semivolatile organic compound
SWMM	stormwater management model
SWMU	Solid Waste Management Unit

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

TAL	Target Analyte List
TCL	Target Compound List
TDS	total dissolved solids
TIC	tentatively identified compound
TOC	total organic carbon
UHSU	upper hydrostratigraphic unit
UTL	upper tolerance limit
VOC	volatile organic compound
WQP	water quality parameter
μCi/g	microCuries per gram
μg/kg	micrograms per kilogram
μg/ℓ	micrograms per liter
%R	relative percent

SECTION 1
INTRODUCTION

This document presents the results of the Resource Conservation and Recovery Act (RCRA) Facility Investigation/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation (RFI/RI) of the 881 Hillside area (Operable Unit No. 1 [OU1]) at the Rocky Flats Plant (RFP). It addresses the characterization of contaminant sources as well as the nature and extent of contamination in soils, groundwater, surface water, sediments, air, and biota. The document also discusses contaminant fate and transport and provides a baseline risk assessment, which consider both ecological and human health risks. The results of the RI and the baseline risk assessment are used to develop recommendations for remedial action.

The investigation summarized in this report is part of a comprehensive, phased program of site characterization, RIs, feasibility studies (FSs), and remedial/corrective actions currently in progress at RFP. These investigations are pursuant to the Department of Energy (DOE) Environmental Restoration Program (formerly known as the Comprehensive Environmental Assessment and Response Program); a compliance agreement between DOE, the Environmental Protection Agency (EPA), and the Colorado Department of Health (CDH) dated July 1986; and the Federal Facility Agreement and Consent Order known as the Interagency Agreement dated January 1991. The program developed by DOE, EPA, and CDH in response to the agreements addresses RCRA and CERCLA issues and has been integrated with the Environmental Restoration Program. In accordance with the Interagency Agreement, the CERCLA terms "remedial investigation" and "feasibility study" in this document are considered equivalent to the RCRA terms "RCRA facility investigation" and "corrective measures study."

The Environmental Restoration Program is designed to investigate and clean up contaminated sites at DOE facilities and involves five major activities (formerly referred to as phases under the Comprehensive Environmental Assessment and Response Program). Activity 1, installation assessments, includes preliminary assessments and site inspections to assess potential environmental concerns. Activity 2, RIs, includes the development and implementation of sampling programs to delineate the magnitude and extent of contamination at specific sites, evaluate contaminant fate and transport, and perform baseline risk assessments. Activity 3, FS, evaluates remedial alternatives and develops remedial action plans to mitigate environmental problems identified during Activity 2. Activity 4, remedial designs/remedial actions, includes design and implementation of site-specific remedial actions selected on the basis of feasibility studies performed during Activity 3. Activity 5, compliance, implements monitoring and performance assessments of remedial actions, and verifies and documents the adequacy of remedial actions carried out under Activity 4. Activity 1 has already been completed at RFP (DOE, 1986; 1992d), and Activities 2, 3, and 4 are currently in progress for OU1.

Activity 2 at OU1 includes Phase I, Phase II, and Phase III RIs. A Phase I field program was completed at OU1 in 1987, and a draft RI report was submitted to EPA and CDH in July 1987 (Rockwell, 1987a). Based on the results of that investigation, Phase II field work was conducted at OU1 in the fall of 1987, and a draft final RI report was submitted to EPA and CDH in March 1988 (Rockwell, 1988a). A draft Phase III RFI/RI work plan was submitted to EPA and CDH in February 1990 (DOE, 1990c), and a final Phase III RFI/RI work plan that incorporated EPA and CDH comments was submitted to EPA and CDH in October 1990 (DOE, 1990e).

Revision 1 of the *Final Phase III RFI/RI Work Plan* (DOE, 1991b), submitted in March 1991, incorporates EPA and CDH comments on the October 1990 submittal. Although not required by the Interagency Agreement, Revision 1 was prepared so that final agency comments were reflected in a single document prior to implementation of the work. This better ensures that the RI and corrective measures study are conducted in accordance with a plan to which all parties are in agreement. In addition, other changes were incorporated into Revision 1 that take into consideration an updated understanding of the site, concurrent study activities at other RFP OUs that may impact OU1, and regulatory issues. Based on comments from EPA and CDH and on additional data collection or evaluation requirements for the Phase III RFI/RI, nine technical memoranda were prepared and attached as amendments to the Work Plan or as precursor documents to the Public Health Evaluation (PHE). The field portion of the ecology work began in April 1991 and ended in April 1992. The field investigations of geology and hydrology (i.e., drilling) began in August 1991 and were completed in January 1992.

Environmental Restoration Program Activity 3 at OU1 included the submittal of a draft FS report for high-priority sites (881 Hillside area) to EPA and CDH in March 1988 (Rockwell, 1988b). EPA comments for both the FS and the Phase II RI reports were received in October 1988. Written responses to comments on the RI and FS reports were submitted to DOE in October 1988 and forwarded to EPA in February 1989 (Rockwell, 1989a). An Interim Measure/Interim Remedial Action (IM/IRA) plan was developed to collect and treat contaminated alluvial groundwater at OU1 (DOE, 1990a). The document was released for public comment during October and November 1989 and was then finalized in January 1990. Construction of the IM/IRA began in November 1991 (EG&G 1991d) and was completed in April 1992. A final remedial action will be proposed based on Phase I, II, and III investigations, as well as the feasibility studies.

1.1 REPORT ORGANIZATION

Section 1 of the Phase III RFI/RI report presents the purpose, background, and IHSS locations and descriptions, and a summary of technical memoranda specific to the Phase III RFI/RI. Included in Section 2 is a discussion of data sets used in and a description of the Phase III field investigation at OU1 as well as other related sampling and monitoring programs, including sampling of radiological "hot spots" identified in IHSS 119.1 and 119.2. Section 3 presents the site characterization including surface features, demography and land use, meteorology and climatology, surface water hydrology, soils, geology, hydrogeology, and ecology. Section 4 discusses data usability and validation procedures, the determination of contaminants at OU1, and the nature and extent of contamination for soils within each IHSS and for other media. Section 5 reviews contaminant fate and transport, including contaminant modeling. Section 6 presents a baseline risk assessment (BRA) that includes a PHE and an Environmental Evaluation (EE). Section 7 summarizes the site physical features, contaminant sources, nature and extent of contamination, fate and transport, and risk assessment, which is followed by conclusions regarding data limitations and recommended remedial action objectives. Section 8 presents references. Volumes I and II contain the text and supporting tables and figures for Sections 1 through 8.

Supporting data were collected and many complex computations were performed as part of the data analysis methods. In order to present these data, a number of appendices have been assembled and attached to this report. The contents of these appendices are as follows:

- Appendices A1-A5 (Volumes III, IV, and V) contain geologic data.
- Appendices B1-B6 (Volumes VI) contain groundwater data, hydraulic conductivity test interpretations, a hydrogeologic assessment of the French Drain, and surface water flow data.
- Appendices C1-C13 (Volume VII) contain analytical results.
- Appendix D (Volume VIII) summarizes the determination of contaminants.
- Appendix E (Volume IX) is the EE.
- Appendix F (Volume X) is the PHE.
- Appendix G (Volume XI) contains the quality assurance data.
- Appendix H (Volume XI) contains the Technical Memoranda associated with the RFI/RI.
- Appendix I (Volume XII) is the Responses to Agency Comments
- Appendix J (Volume XII) is the Distribution List.

The table of contents in each Appendix includes the number of the volume in which material is located. This facilitates use of appendices that span more than one volume.

1.2 PURPOSE OF REPORT

This OU1 Phase III RFI/RI Report presents the findings of the Phase III field investigation, data interpretation, and risk assessment. The 17 specific objectives of this investigation as detailed in Section 3.3 of the *Final Phase III RFI/RI Work Plan* (DOE, 1991b) are briefly described below. Table 1-1 lists the objectives along with the work performed to achieve these objectives.

Characterize Site Physical Features

1. Determine the extent of saturation and groundwater flow directions for the unconfined flow system both spatially and temporally.

2. Describe the interaction between the surface and groundwater pathways.

3. Quantify material properties.

4. Describe all soils and rock materials.

5. Verify the hydrogeologic site conceptual model for OU1 (DOE, 1991b).

Characterize Contaminant Sources

6. Characterize the nature and distribution of waste materials remaining on site.

7. Characterize soils in proximity to the removed wastes as potential contaminant sources.

8. Identify which sites or subareas of sites are sources of contaminants in groundwater.

Characterize the Nature and Extent of Contamination

9. Determine the horizontal and vertical extent of surficial radionuclide (RAD) soil contamination due to wind dispersion.

10. Determine the nature and extent of groundwater contamination in surficial materials.

11. Determine the location and extent of weathered and unweathered sandstone units and associated contamination.

12. Characterize the quality of the surface water.

13. Characterize RADs in Woman Creek sediments.

14. Identify and implement data management procedures.

15. Collect data of sufficient quality to facilitate development of a site conceptual model and compare them to applicable or relevant and appropriate requirements (ARARs).

Provide a Baseline Risk Assessment

16. Describe contaminant fate and transport.

17. Assess the threat to public health and the environment from the "No Action" remedial alternative.

1.3 BACKGROUND

RFP is a government-owned, contractor-operated facility that is part of the nationwide nuclear weapons production complex. RFP is located in northern Jefferson County, Colorado, approximately 16 miles (26 kilometers) northwest of Denver (Figure 1-1), and comprises approximately 6,550 acres (2,652 hectares) of land in Sections 1 through 4 and 9 through 15 of Township 2 South, Range 70 West, 6th Principal Meridian. Major buildings are located within the industrial area, which encompasses approximately 400 acres (162 hectares). The industrial area is surrounded by a buffer zone of approximately 6,150 acres (2,490 hectares).

1.3.1 Plant Operations

The Atomic Energy Commission operated RFP from 1951 to January 1975 when the commission was dissolved. At that time, responsibility for the plant was assigned to the Energy Research and Development Administration, which was succeeded by DOE in 1977. Dow Chemical U.S.A., an operating unit of the Dow Chemical Company, was the prime contractor responsible for operating RFP from 1951 until June 30, 1975. Rockwell International was the prime contractor responsible for operating RFP from July 1, 1975, until December 31, 1989. EG&G Rocky Flats, Inc., became the prime contractor at RFP on January 1, 1990, and currently operates the plant.

RFP is currently in transition from a defense production facility to a facility whose planned future missions include environmental restoration, waste management, maintaining production contingency, and eventual decontamination and decommissioning. Until January 1992, the plant was operated as a nuclear weapons research, development, and production complex. RFP fabricated nuclear weapon components from plutonium, uranium, beryllium, and stainless steel. Parts made at the plant were shipped elsewhere for assembly. Support activities included chemical recovery and purification of recyclable transuranic RADs and research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics (Rockwell, 1987b).

Both radioactive and nonradioactive wastes were generated in the production process. Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed wastes, and off-site disposal of solid radioactive materials at another DOE facility. In the past both storage and disposal of hazardous and radioactive wastes occurred on the site. The preliminary assessment performed under the Environmental Restoration Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination (DOE, 1986).

1.3.2 <u>OU1 Area Site Locations and Descriptions</u>

Environmental Restoration Program investigations performed during Activity 1 (installation assessment) identified 12 individual hazardous substance sites (IHSSs) within OU1 (DOE, 1986). The Interagency Agreement, however, lists only 11 sites within OU1. The twelfth, IHSS 177, is being investigated as part of the RFI/RI for OU10 (IAG, 1991). The 11 IHSSs within OU1 (Figure 1-2) are the following:

- Oil Sludge Pit Site (IHSS 102)
- Chemical Burial Site (IHSS 103)
- Liquid Dumping Site (IHSS 104)
- Out-of-Service Fuel Tank Sites (IHSSs 105.1 and 105.2)
- Outfall Site (IHSS 106)
- Hillside Oil Leak Site (IHSS 107)
- Multiple Solvent Spill Sites (IHSSs 119.1 and 119.2)
- Radioactive Site - 800 Area Site #1 (IHSS 130)
- Sanitary Waste Line Leak (IHSS 145)

OU1 was selected as a high-priority site because of the elevated concentration of volatile organic compounds (VOCs) detected in the groundwater, the relatively permeable soils, and the proximity of the area to a surface water drainage. Based on previous investigations, the principal chemical contaminants of concern (COCs) in alluvial or unconfined groundwater at OU1 were tetrachloroethane, trichloroethene, 1,1,1-trichloroethane, and 1,1-dichloroethene (Rockwell, 1986). The following historical information on each IHSS was compiled from the *Final Historical Release Report* (HRR) (DOE, 1992d) and the *Final Phase III RFI/RI Work Plan* (DOE, 1991b). Based on information discovered during the historical releases investigation, several of the IHSS names and disposal histories were modified or changed to clarify the location of the IHSS or to better match the history of waste disposal at the site. These modifications are discussed in the following sections; however, the original IHSS names are used because they correspond to the names listed in the Interagency Agreement and the Work Plan.

1.3.2.1 Oil Sludge Pit Site (IHSS 102)

In 1958, approximately 30 to 50 drums of nonradioactive materials were dumped into a pit south of Building 881. Material in the drums consisted of sludge from oil tank cleanouts, possibly from the two No. 6 fuel oil tanks designated as IHSSs 105.1 and 105.2 (DOE, 1986). The pit was backfilled when disposal operations ceased (DOE, 1992d).

Previous investigations report various dimensions and locations for IHSS 102. In the RCRA Part B Operating Permit (Section 3004[u]), IHSS 102 is located 180 feet south of Building 881 and has dimensions of 50 feet by 80 feet (Rockwell, 1987b). The pit location from the RCRA permit was revised based on an aerial photography study conducted as part of the Phase II RI. In the Phase II Report (Rockwell, 1988a) and the Phase III Work Plan (DOE, 1991b), IHSS 102 is located 500 feet south of Building 881 and has dimensions of 40 feet by 70 feet. The HRR (DOE, 1992d) questioned the Phase II location based on the statements made in an environmental inventory (Owen and Steward, 1973). However, the HRR also stated that there was no indication that any dumping took place. Also, the inventory provided no basis for changing the location of IHSS 102 from the location cited in the Phase II Report, and, subsequently, targeted in the Phase III Work Plan. This is the site that was investigated in the Phase III RFI/RI.

As a result of the conflicting information regarding the location of IHSS 102, a review of historical aerial photographs was conducted. A 1955 aerial photograph clearly shows a rectangular-shaped impoundment whose location correlates well with the location shown in the Phase III Work Plan and on Figure 1-2 of this report. The interior of the impoundment appears black on the 1955 aerial photograph which contrasts sharply with the lighter colored surrounding landscape (Figure 1-3). Evidence of IHSS 102 can also be seen in a 1963 aerial photograph, however, its shape appears irregular and there is little contrast in coloration. The feature seen on the 1963 photograph is interpreted as representing the post-closure condition of the IHSS.

1.3.2.2 Chemical Burial Site (IHSS 103)

An area south of Building 881 was reportedly used to bury unknown chemicals (DOE, 1986). The exact location, dates of use, and contents of the site are unknown. The draft Comprehensive Environmental Assessment and Response Program report and the Work Plan state that a pit, apparently filled with liquid, is evident approximately 150 feet southeast of Building 881 on 1963 aerial photographs (DOE, 1986; 1991b). The pit is circular in shape and measures approximately 50 feet in diameter. No documentation was found during the historical release investigation that verifies the existence of this site, and personnel who were employed by RFP in the 1960s could not recall any such incidents of dumping (DOE, 1992d). It is possible that this site may have been confused with IHSS 109 in OU2 (Trench T-2), which is located east of OU1. IHSS 109 is believed to have been used for disposal of sewage sludge, liquid waste, and crushed drums that formerly contained oil (DOE, 1992d).

1.3.2.3 Liquid Dumping Site (IHSS 104)

An area east of Building 881 was reportedly used for disposal of unknown liquids and empty drums prior to 1969 (DOE, 1986). The report does not provide the exact location or dimensions of the pit. In the RCRA Part B Operating Permit, IHSS 104 has dimensions of approximately 50 feet by 50 feet, based on 1965 aerial photographs (Rockwell, 1987b). Further review of these historical aerial photographs as part of the Phase II RI indicated that the identified "pit" may be a shadow on the photograph (Rockwell, 1988a). It was concluded in the Work Plan that IHSS 104 is likely the same as IHSS 103 (DOE, 1991b). No documentation was found during the historical release investigation that verifies the existence of this site, and personnel who were employed by RFP in the 1960s could not recall any such incidents of dumping this close to Building 881 (DOE, 1992d). These personnel concluded that IHSS 104 may have been confused with IHSS 109 in OU2 (Trench T-2), which is located east of OU1. IHSS 109 is believed to have been used for disposal of sewage sludge, liquid waste, and crushed drums that formerly contained oil (DOE, 1992d).

1.3.2.4 Out-of-Service Fuel Tank Sites (IHSSs 105.1 and 105.2)

Two out-of-service No. 6 fuel tanks are located immediately south of Building 881. These tanks were used to store diesel fuel from 1958 through 1976 (DOE, 1991b). After 1976 they were filled with asbestos-containing material and then later with concrete (Rockwell, 1987b). IHSS 107, the Hillside Oil Leak Site, may have been caused by leakage from these tanks (DOE, 1992d). In the HRR (DOE, 1992d), IHSSs 105.1 and 105.2 are referred to as the Building 881 Westernmost Out-of-Service Fuel Tank and Building 881 Easternmost Out-of-Service Fuel Tank, respectively. However, maps from the same reference orient these tanks north–south, as does Figure 1-2. This contradiction remains unresolved.

1.3.2.5 Outfall Site (IHSS 106)

A 6-inch-diameter iron outfall pipe is present south of Building 881. The outfall, originally described as a 6-inch vitrified clay pipe (Rockwell, 1987a; 1988b), originates at the Building 887 lift station and is the clean-out pipe for an overflow line from the Building 881 cooling tower (DOE, 1992d). The outfall was used for discharge of untreated sanitary wastes in the 1950s and 1960s (DOE, 1992d). In 1955, high bacterial counts were reported from water samples collected at the outfall and east along Woman Creek to the cattle fence. Due to concern about discharges from the outfall entering Woman Creek, several small retention ponds and an interceptor ditch were built in 1955 and 1979, respectively, to divert the outfall water to Pond C-2. After discharges of sanitary wastes were halted, the outfall pipe continued to be used for discharge of cooling water blowdown into the late 1970s. Cooling water was found to be discharging from the outfall onto 881 Hillside in December 1977 (DOE, 1991b).

1.3.2.6 Hillside Oil Leak Site (IHSS 107)

Oil was discovered flowing down 881 Hillside south of Building 881 in May 1973. The oil spill was contained with straw, and the oil-soaked straw and soil were removed and disposed in the present landfill north of the plant (Rockwell, 1987b). Oil was also found in a 60-inch-diameter standpipe located just south of the security fence. The oil was traced to the foundation drain (also called the footing drain) from Building 881 (DOE, 1992d). A concrete skimming pond was built below the foundation drain outfall to contain the oil flowing from the foundation drain, and an interceptor ditch was constructed to prevent oil-contaminated water from reaching Woman Creek (Owen and Steward, 1973). The skimming pond was removed during construction of the French Drain as part of the IM/IRA remedial action in 1992.

The source of the oil was believed to be the two out-of-service fuel tanks (IHSSs 105.1 and 105.2) because the foundation drain passes directly underneath the tanks. Both tanks and associated lines were pressure tested in 1973; and no leaks were detected (DOE, 1991b). Several scenarios were presented in the HRR to explain the oil leak. It was postulated that oil spills occurred as a result of the tanks being overfilled, creating an underground oil reservoir. Oil may have seeped out of the hillside from this underground reservoir in 1973 (DOE, 1992d). Alternatively, the oil may have originated from other known spill sites at OU1 (DOE, 1992d). IHSS 107 is referred to as the Building 881 Hillside Oil Leak Site in the HRR (DOE, 1992d).

1.3.2.7 Multiple Solvent Spill Sites (IHSSs 119.1 and 119.2)

Beginning in approximately 1968, two areas east of Building 881 and along the southern perimeter road were used for scrap metal and drum storage. The drums contained unknown quantities and types of solvents and wastes (Rockwell, 1987b). The scrap metal may have been coated with residual oils and/or hydraulic coolants (DOE, 1992d). Aerial photographs from 1969 and 1970 show material stored in piles and rows (DOE, 1992d). Scrap metal and drums were removed in November and December 1971, and disturbed soil was revegetated the following spring (DOE, 1992d). IHSS 119.1 is the larger western drum and scrap metal storage area, and appears to have contained mostly drums in the southern part of the IHSS and mostly scrap metal in the northern part, although material was moved around frequently as documented by the aerial photographs. IHSS 119.2 is the smaller eastern drum and scrap metal storage area and appears to have contained mostly scrap metal, although poor photograph resolution does not permit definitive documentation. Figure 1-2 shows the drum and scrap metal storage areas within each site. The locations of stored drums are discussed in more detail in Section 4.

There was no documentation found during the historical release investigation that supports the use of these sites as solvent storage areas, as stated in the RCRA Part B Operating Permit (Rockwell, 1987b) and in the Work Plan (DOE, 1991b). Historical evidence gathered during the investigation indicates that scrap metal was stored at these sites and, therefore, IHSSs 119.1 and 119.2 were referred to as Scrap Metal Storage Areas in the HRR to better match the history of waste disposal (DOE, 1992d). However, Phase II and Phase III investigations indicated the presence of solvent compounds in the subsurface.

1.3.2.8 Radioactive Site - 800 Area Site #1 (IHSS 130)

An area east of Building 881 and northwest of IHSS 119.1 was used between 1969 and 1972 to dispose of soil and asphalt contaminated with low levels of plutonium. IHSS 130 is referred to as the Contaminated Soil Disposal Area East of Building 881 in the HRR to better match the history of waste disposal (DOE, 1992d); the site is included in the discussion of the 900 Area at RFP in that report. The materials at this site were derived from three sources at RFP described below.

In September 1969, plutonium-contaminated soil and asphalt were removed from the west side of Building 776 and placed in the OU1 area at what is now IHSS 130 (Owen and Steward, 1973). The soil and asphalt were contaminated during the May 11, 1969 fire in Building 776, and had an estimated average plutonium activity of 7.4 disintegrations per minute per gram (3.36 picoCuries per gram [pCi/g]). The total plutonium concentration of this material was estimated at 14 milligrams (864 microCuries) (Putzier, 1970). Material from the 1969 fire was buried under 1 to 2 feet of fill dirt (Owen and Steward, 1973).

In August 1970, a section of the Central Avenue roadway between Eighth and Tenth Streets was removed and placed in the OU1 area at what is now IHSS 130 (Owen and Steward, 1973). This stretch of road was radioactively contaminated in June 1968 by a leaking drum in transit from the 903 Drum Storage Site to Building 774 (Owen and Steward, 1973). The soil and asphalt from these two sources amounts to approximately 320 tons (DOE, 1992d) or 250 cubic yards (Illsley, 1978).

In 1972, approximately 60 cubic yards of plutonium-contaminated soil were removed from around the Building 774 process waste tanks and placed in the OU1 area (Owen and Steward, 1973). The soil was placed on top of previously deposited soils at IHSS 130 and covered with approximately 3 feet of fill dirt (Illsley, 1978). The estimated total long-lived alpha activity of this soil is less than 0.154 pCi/g (Illsley, 1978).

1.3.2.9 Sanitary Waste Line Leak (IHSS 145)

In January 1981, the 6-inch, cast-iron sanitary sewer line that originates at the Building 887 lift station leaked on the hillside south of Building 881 (DOE, 1992d). That month an earthen dike was constructed to prevent the spill from entering the South Interceptor Ditch (SID), and the line was repaired. The line had conveyed sanitary wastes and low-level radioactive laundry effluent to the sanitary treatment plant from about 1969 to 1973 (DOE, 1992d). A recent review of Building 881 construction drawings for the historical releases investigation indicates that the only sanitary waste lines presently located south of the building are the 6-inch cast-iron sanitary sewer line that originates at the Building 887 lift station and a 6-inch vitrified clay pipe that runs east–west into Building 887 (DOE, 1992d). This appears to contradict Section 3004(u) of the RCRA Part B Operating Permit, which states that the line is 4-inch cement/asbestos pipe (Rockwell, 1987b).

1.3.3 Previous Investigations

Various studies have been conducted at RFP to characterize environmental media and to assess the extent of radiological and chemical contamination in the environment. These studies include detailed descriptions of the plant-site geology, several drilling programs that resulted in the construction of approximately 60 monitoring wells by 1982, surface water and groundwater investigations, an environmental impact statement, an electromagnetic survey, a soil gas survey, and numerous reports of routine environmental monitoring. In addition to these selected sitewide studies, many investigations have been completed specifically at OU1. Table 1-2 provides a chronological listing of documents pertaining to specific environmental investigations at OU1, beginning with the most recent. Selected investigations that augment the OU1 RFI/RI are discussed below.

Two major investigations were completed at RFP in 1986. The first was the Environmental Restoration Program Phase I installation assessment (DOE, 1986), which included analyses and identification of current operational activities, active and inactive waste sites, current and past waste management practices, and potential environmental pathways through which contaminants could be transported. A number of sites were identified that could potentially have adverse impacts on the environment. These sites were designated as solid waste management units (SWMUs) by Rockwell (1987b) and were divided into three categories:

- Hazardous waste management units that will continue to operate and need a RCRA operating permit.
- Hazardous waste management units that will be closed under an RCRA interim status permit.
- Inactive waste management units that will be investigated and cleaned up under RCRA Section 3004(u) or under CERCLA.

The Interagency Agreement redefines the SWMUs within the second and third categories as IHSSs. All IHSSs in OU1 fall within the third category.

The second major investigation involved a hydrogeologic and hydrochemical characterization of the entire site. Plans for this study were presented by Rockwell (1986). Four areas were identified as significant contributors to environmental contamination, with each area containing a number of sites. The four areas were 881 Hillside, 903 Pad, Mound, and East Trenches. The 881 Hillside was subsequently designated OU1 and the other three areas as OU2.

Since the Phase II RI, four other RFP-wide studies have been conducted that further supplement RFI/RI activities at OU1: the geologic characterization program, the background geochemical characterization study, the surface water and sediment geochemical characterization study, and the historical releases investigation. The RFP geologic characterization program (EG&G 1990a; 1991g) was undertaken to develop a comprehensive geologic framework that can be used to define the direction, rate, and volume of groundwater flow; delineate contaminant migration pathways; and characterize potential seismic risks. The study was intended to be used to formulate hydrogeologic models, design and implement groundwater monitoring programs, and plan remedial activities.

As part of the geologic characterization program, geologic mapping and shallow, high-resolution seismic reflection surveys were conducted at RFP (Rockwell, 1989b and EG&G 1990b; 1991c; 1991e; 1992b). A geologic map of a 60-square-mile area surrounding RFP was produced; the Upper Cretaceous Fox Hills Sandstone, Laramie Formation, and Arapahoe Formation were described, and criteria were developed for their identification in the surface and subsurface; previously mapped faults were verified and further characterized; new areas of structural deformation were identified; inconsistencies in previously published geologic maps (Spencer, 1961; Van Horn, 1972; Hurr, 1976) were resolved; and the stratigraphy at RFP was directly tied to the regional stratigraphy on the basis of established lithologic criteria (EG&G, 1992b).

Shallow, high-resolution seismic reflection surveys were conducted primarily to acquire stratigraphic information. Sandstone channels were mapped in bedrock beneath OU2 and east of RFP along Indiana Street (Rockwell, 1989b and EG&G, 1991c; 1991e). Structural features were identified in the northwest part of the buffer zone, in the central part of the plant (EG&G, 1990b), beneath OU2 (EG&G, 1991c), and near Indiana Street (EG&G, 1991e). A deep seismic reflection survey was conducted, from Coal Creek Canyon to Jefferson County Airport and across the buffer zone north of the plant, primarily to acquire structural information (EG&G, 1992c). None of the seismic data were acquired at OU1; however, stratigraphic information and structural trends may be projected into the area and used to interpret site characteristics.

The second and third studies that augment site-specific RFI/RI activities at OU1 are the background geochemical characterization study and the surface water and sediment geochemical characterization study. The background geochemical characterization study summarizes background data for groundwater, surface water, sediments, and geological materials, and identifies preliminary statistical boundaries of background variability (DOE, 1992f). Similarly, the surface water and sediment geochemical characterization study (EG&G, 1992a) identifies surface water and sediment characteristics and documents general geochemical trends associated with environmental contamination at RFP. Seeps and depressions in OU1 were sampled as a part of this study.

The fourth study, the historical releases investigation, was required by the Interagency Agreement to provide a complete listing of all spills, releases, and/or incidents involving hazardous substances that occurred since the inception of RFP operations. Information describing individual release sites was gathered by background research, file review, site visits and photography, and employee interviews. Release sites, including existing RFP IHSSs, were designated as potential areas of concern (DOE, 1992d).

Previous environmental investigations performed at OU1 include Phase I and Phase II RIs (Rockwell, 1987a; 1988a) and the *French Drain Geotechnical Investigation* (EG&G, 1990e) in support of the IM/IRA (DOE, 1990a). The Phase I RI began in March 1987 in accordance with the plans presented by DOE (1987a; 1987b). Phase II field work was performed after the Draft Phase I Report was submitted and after meetings with EPA and CDH to plan further work based on Phase I results. Seventeen boreholes, six alluvial monitoring wells, and one bedrock monitoring well were drilled and installed for the Phase I program. Twenty-three boreholes, 16 alluvial monitoring wells, and 4 bedrock monitoring wells were drilled and installed for the Phase II program. Figure 1-4 shows the locations of Phase I and Phase II boreholes and wells. While the Phase I and Phase II RIs were limited in scope, they provided adequate preliminary information about waste source locations, waste source characterization, subsurface geology, and hydrology to facilitate the design of a thorough and comprehensive Phase III RI.

The IM/IRA recently completed at OU1 includes a French Drain designed to collect contaminated alluvial groundwater from OU1 and prevent further downgradient migration, thereby alleviating a potential long-term threat to human health and the environment. A geotechnical investigation was performed at OU1 as part of the IM/IRA to evaluate the site characteristics along the proposed French Drain alignment (EG&G, 1990e). Thirty-eight boreholes were drilled on approximately 100-foot centers and sampled for geotechnical testing (Figure 1-5). Geotechnical testing was conducted, and chemical analyses were run on soil and bedrock samples collected from selected borings. Twenty-four boreholes were packer tested, and four alluvial piezometers were installed along the eastern end of the french drain alignment (DOE, 1991b). Construction of the French Drain began in November 1991 and was completed in April 1992. Appendix A4 of this report includes cross sections depicting the geology of the French Drain excavation walls and tables summarizing geotechnical data and hydraulic properties of samples collected in the french drain.

The French Drain was constructed by excavating a trench approximately 1,435 feet in length along the downgradient boundary of OU1. The trench is keyed into bedrock material exhibiting a hydraulic conductivity on the order of 1 x 10^{-6} centimeters per second (cm/sec). A permeable membrane (geotextile) was placed on the north wall of the excavation to allow for capture of the alluvial groundwater. An impermeable polyvinyl chloride membrane was placed on the south wall of the French Drain to prevent captured groundwater from migrating downgradient of the system, and perforated pipe was installed in the keyway for collection of groundwater. The keyway was then backfilled with gravel and covered with geotextile, and Class I soil was placed on top of the membrane to a depth of approximately 1 foot. Finally, the entire excavation was backfilled with material excavated during the French Drain construction.

1.4 SUMMARY OF TECHNICAL MEMORANDA AND STANDARD OPERATING PROCEDURE ADDENDA

Because of the unknown nature of many of the sites at RFP and the iterative nature of the RFI/RI process, additional data requirements and analyses may be identified throughout the process. When this occurs, the Interagency Agreement stipulates that DOE submit technical memoranda to EPA and CDH documenting the need for additional data and identifying data quality objectives (DQOs). Upon agency approval, these technical memoranda are attached as amendments to approved work plans. Nine technical memoranda were prepared as part of the Phase III RFI/RI for OU1 (Table 1-3). They are the following:

- Technical Memorandum No. 1 - Chemical Analysis Plan
- Technical Memorandum No. 2 - Responses to Comments on the OU1 Phase III RFI/RI Work Plan (Revision 1)
- Technical Memorandum No. 3 - Multiple-Well Pumping Test Plan
- Technical Memorandum No. 4 - Tracer Test Plan
- Technical Memorandum No. 5 - Surface Soil Sampling and Analysis Plan
- Technical Memorandum No. 6 - Exposure Scenarios
- Technical Memorandum No. 7 - Description of Models for the Public Health Evaluation
- Technical Memorandum No. 8 - Contaminant Identification
- Technical Memorandum No. 9 - Toxicity Constants

In addition, three standard operating procedure (SOP) addenda were prepared to supplement the sampling procedures in the SOPs and the Phase III RFI/RI Work Plan (Table 1-3). They are the following:

- Soil Sampling for Geotechnical Analysis
- Soil Sampling for Total Organic Carbon Analysis
- Hand-Auger Sampling

The contents of the nine technical memoranda and three SOP addenda are summarized below. The technical memoranda are considered attachments to the Work Plan and are available in their entirety in the Administrative Record and public reading rooms with the Work Plan. They are also included in Appendix H of this report.

1.4.1 Chemical Analysis Plan

Technical Memorandum No. 1 is the chemical analysis plan submitted as an addendum to the Work Plan in August 1991 (DOE, 1991e). The purpose of the plan was to screen out, from the list of Target Compound List (TCL) and Target Analyte List (TAL) constituents, those analytes that had appeared either inconsistently during previous sampling rounds or in low concentrations, in order to make the analytical results more tailored to the site, concise, and meaningful. The plan evaluated the historical chemical data set for OU1 and presented an amended analytical strategy for the Phase III investigation.

The site-specific TAL was defined by tabulating and summarizing existing analytical data by analytical suite. The tabulation included the total number of analyses and the number of detections for each chemical. Three outcomes were possible from this tabulation:

1. One or more chemicals from an analytical suite were not detected at a given detection limit in a specified media.

2. One or more chemicals from an analytical suite were detected either inconsistently or at low concentrations in a specified media.

3. One or more chemicals from an analytical suite were consistently detected in a specified media.

In the first case, the analytical suite was eliminated provided that historical data were of adequate quality, usability, and were representative of the site. Evaluation of representativeness included spatial consideration. In the second case, the analytical suite was eliminated provided that data quality, spatial representativeness, temporal variations, concentrations, chemical fate and transport, and human health risks were assessed. In the third case, the analytical suite was retained in the Phase III investigation to better characterize the medium, particularly if the chemicals are mobile and toxic. In this manner, Phase III analytical suites were selected for each medium. The selection process for each suite in each medium is briefly described below.

In the groundwater and surface water media, VOCs were detected in 773 out of 14,898 analyses in Phases I and II. Detected concentrations ranged from 1 to 72,000 micrograms per liter

($\mu g/\ell$). Because VOCs were detected at high concentrations, the plan recommended that Phase III samples be analyzed for all EPA Contract Laboratory Program (CLP) TCL organics. Acid-extractable semivolatile organic compounds (SVOCs) were detected at low concentrations in 6 out of 656 analyses in Phases I and II. Because there is no documentation regarding the disposal of wastes containing acid-extractable compounds, and because the detections occurred infrequently and at low concentrations, the plan recommended that this analytical suite be eliminated from OU1 monitoring. Similarly, base/neutral extractable SVOCs were detected at low concentrations in 28 out of 2,192 analyses in Phases I and II. Because base/neutral extractable compounds were detected infrequently and at low concentrations, the plan recommended that this analytical suite be eliminated from OU1 monitoring. Pesticides were detected at low concentrations in 4 out of 1,227 analyses in Phases I and II. Because there is no documentation regarding the disposal of pesticides at OU1, and because they were detected infrequently and at low concentrations, the plan recommended they be eliminated from the program. Polychlorinated biphenyls (PCBs) were not detected in groundwater or surface water analyses in Phases I and II. Because there is no documentation regarding the disposal of PCBs at OU1, the plan recommended this analytical suite be eliminated from OU1 monitoring.

In the soils and sediments media, VOCs were detected in 361 out of 4,955 analyses performed during Phases I and II. Because VOCs were detected at levels significantly above method detection limits, and VOCs were known to have been disposed of at OU1, the plan recommended that Phase III samples be analyzed for all TCL organics. Acid-extractable SVOCs were detected at low concentrations in only 3 out of 2,572 Phase I and II analyses. Because there is no documentation regarding the disposal of wastes containing acid-extractable SVOCs at OU1, and because the detections occurred infrequently and at low concentrations, the plan recommended that this analytical suite be eliminated from OU1 monitoring. Base/neutral extractable SVOCs were detected at low concentrations in 208 out of 8,184 analyses in Phases I and II. Most of the analytes detected were phthalate esters, and a few were polynuclear aromatic hydrocarbons (PAHs). Neither of these analytes/analyte groups are associated with past waste disposal practices, nor are they mobile in the environment. Because they were detected infrequently and at low concentrations, the plan recommended they be eliminated from OU1 monitoring. No pesticides were detected in Phase I and Phase II soil and sediment samples; therefore, the plan recommended that they also be eliminated from OU1 monitoring. PCBs were detected at low concentrations in only 3 out of 4,232 Phase I and II analyses. Because they occurred infrequently and at low concentrations, and because they are immobile in the environment, the plan recommended they be eliminated from OU1 monitoring.

EPA and CDH reviewed the chemical analysis plan in Technical Memorandum No. 1 after it was submitted in August 1991. Based on comments from EPA and CDH, modifications were made to the analytical suites and/or analytical methods proposed for some borehole and monitoring well locations. Table 1-4 outlines EPA/CDH modifications to the Phase III RFI/RI chemical analysis plan by IHSS and by borehole/monitoring well. Table 1-5 presents the final analytical suite that was implemented for each borehole and monitoring well.

1.4.2 Responses to Comments on the OU1 Phase III RFI/RI Work Plan

Technical Memorandum No. 2 (DOE, 1991f) is the DOE response to the August 1, 1991, EPA comments on the revised Phase III OU1 RFI/RI Work Plan (DOE, 1991b). The memorandum was limited to responses to key EPA concerns identified in the cover letter to the comments. Six concerns, which are summarized below, were addressed in the memorandum.

The first concern was that surface soil scrape sampling should extend into IHSS 130. DOE responded that sampling to characterize the distribution of plutonium and americium in surface soils would be conducted in IHSS 130 and that surface soil sampling for actinides in OU1 had been completed in August 1991.

The second concern was that surface contaminant particle size should be evaluated for the risk assessments. DOE responded that particle size distribution analysis was to be performed in three OU1 areas that were identified for vertical profiling of the distribution of plutonium, americium, and uranium. In addition, the concentration of actinides within the sand, silt, and clay fractions was to be analyzed for certain samples, including samples taken from the top 3 centimeters (cm) of soil.

The third concern was that sampling should be conducted to characterize nonaqueous-phase liquids, if present. DOE responded that sampling would be performed on select wells within

IHSSs 119.1, 119.2, 105.1, and 105.2 to determine whether light nonaqueous-phase liquids (LNAPLs) or dense nonaqueous-phase liquids (DNAPLs) were present and, if so, to chemically characterize the liquids.

The fourth concern was that adequate air monitoring should be conducted to completely evaluate the air exposure pathway in the risk assessment and EE. DOE stated that the EPA concern over adequate air monitoring was the result of the vague way in which the Work Plan described how the nature and extent of contamination via the air pathway would be analyzed, and that, in actuality, the results of the in-place surface soil sampling program and the air sampling program would provide for a complete evaluation of the air pathway in the risk assessment and EE.

The fifth concern was that ARARs should be evaluated as presented in the specific comments in Section 7 of the Work Plan. DOE responded that the EPA comments pertaining to ARARs have been reviewed and that the comments would be addressed in the Phase III RFI/RI Report.

The sixth concern was that the risk of laboratory contamination should be carefully controlled and that previous data showing elevated concentrations of potential laboratory contaminants be verified. The concern was that contamination not attributable to laboratory contamination be considered as contamination from a waste source. DOE responded that both laboratory- and field-introduced contamination of samples would be addressed and controlled by selecting a laboratory with a track record for minimizing laboratory-introduced contamination, by strictly adhering to field SOPs, and by modifying field techniques and quality control protocols to minimize introduction of phthalate contamination in samples during handling and shipping. DOE agreed with EPA that the presence of contaminants in samples that could not be attributed to laboratory contamination would be considered as originating from waste sources.

Each of the six EPA concerns is addressed in the Phase III RFI/RI Report.

1.4.3 Multiple-Well Pumping Test Plan

Technical Memorandum No. 3 is the multiple-well pumping test plan that was submitted as an addendum to the Work Plan in November 1991 (DOE, 1991h). The tests were proposed for the

Woman Creek alluvium to develop better estimates of solute travel times. The plan described techniques that were specific to the three multiple-well (15 wellpoint array) pumping tests for OU1, although these techniques were compatible with and supplementary to Ground Water SOP GW2.08, *Aquifer Pumping Tests* (EG&G, 1991a). During implementation, because of low-yield aquifer conditions, two of the tests were canceled.

The multiple-well pumping test plan recommended that an exploratory borehole be drilled at the multiple-well test location to determine site-specific hydrogeologic conditions (i.e., depth to water table, depth to the base of the saturated alluvial aquifer, initial saturated thickness of the aquifer, and grain-size distribution of aquifer materials). Subsequently, 15 wellpoints were installed in a 3-well by 5-well array with the rows of 5 wells oriented perpendicularly to the estimated direction of groundwater flow, and installed on nominal 2.5-foot centers (increased from the proposed 2-foot centers because of drilling conditions). The wellpoints were developed using methods described in Ground Water SOP GW2.08, *Aquifer Pumping Tests* (EG&G, 1991a), and the aquifer allowed to return to an equilibratory hydraulic condition. The central well of the wellpoint array was to be used as the pumping well during the test, and all other wells used for observation of groundwater level fluctuations.

The plan recommended that a step-drawdown test be conducted to provide information on the efficiency of the pumping well and to establish a flow rate that could be sustained during the constant-rate pumping test. Ultimately, two step-drawdown tests were conducted. Water levels in the pumping well and observation wells and time-drawdown measurements were collected during the step-drawdown tests. Results were analyzed, and a pumping rate was selected for use in the multiple-well constant-rate pumping test based on the drawdown curve calculations.

The plan called for a constant-rate pumping test to be conducted to estimate the transmissivity and specific yield of the aquifer. The central well of the array was pumped for a specified period, and water levels were measured in all wells before, during, and after the pumping to record both the drawdown and recovery of the piezometric surface.

1.4.4 Tracer Test Plan

Technical Memorandum No. 4 is the multiple-well tracer test plan that was submitted as an addendum to the Work Plan in November 1991 (DOE, 1991i). It described techniques that were specific to the tracer tests for OU1 and was compatible with and supplementary to Ground Water SOP GW2.07, *Tracer Tests* (EG&G, 1991a).

The plan recommended that following wellpoint development and sampling, a tracer evaluation test be conducted at a single wellpoint to assess the appropriateness of three different tracers for use in the multiple-well tracer tests. Tracers that were evaluated were distilled water, rhodamine WT dye, and potassium bromide. Rhodamine WT dye and potassium bromide were recommended in the plan because of their conservative behavior, absence in the hydrogeologic environment, and ease of detection in aqueous samples. During implementation, plans to test rhodamine WT dye were canceled because satisfactory results were obtained with bromide.

The plan required that potassium bromide standards be prepared and sent to the laboratory for confirmatory analysis before the multiple-well tests were conducted. These standards were used to develop a calibration curve for the analysis of bromide tracer test breakthrough data. Groundwater samples collected at the site of the tracer evaluation test prior to startup of the test were also submitted for laboratory analysis. All other fluids were analyzed in the field.

The plan recommended using an injection tube to inject the tracer into the aquifer. When injection was complete, a peristaltic sampling pump was used to withdraw water from the aquifer at a rate equal to that of injection. Flow rate, time, and water levels were recorded continuously during the injection portion of the test. Samples were collected and analyzed in the field to determine whether tracer breakthrough occurred. The results from the *in situ* testing of each tracer were analyzed to select the most appropriate and detectable tracer for use in the multiple-well tracer tests.

A multiple-well tracer test was conducted using the same 15 wellpoint array used in the multiple-well pumping tests. Fifteen wellpoints were installed in a 3-well by 5-well array with the rows of 5 wells oriented perpendicular to the estimated direction of groundwater flow. The wells were installed on 2.5-foot centers as stated in the discussion for the pump test. In this arrangement, the five upgradient wells on one side of the array served as injection wells, the five downgradient wells on the other side of the array served as withdrawal or tracer recovery wells, and the central row of five wells served as water-level observation wells. The tracer test was conducted as a constant hydraulic gradient test. Groundwater samples were collected from the middle well of the injection row, the middle well of the observation row, and the three middle wells of the withdrawal row.

The plan recommended injecting groundwater into the five injection wells so that the hydraulic head within each well was held constant at a level of 1 foot higher than the static water table, ensuring that the fluctuations in elevation were no more than $\pm$ 0.2 foot. The withdrawal wells were pumped at a rate that maintained the groundwater elevation in each well at approximately static water levels (also $\pm$ 0.2 foot). When a steady-state condition was established, tracer solution was introduced at a constant rate at the five injection wells. The tracer was injected continuously until breakthrough was observed at the withdrawal wells.

The plan called for sampling at regular intervals. Samples were analyzed in the field to determine when tracer breakthrough occurred, and water level data were collected frequently during the test. The test was terminated when bromide concentrations in the extraction wells and observation wells stabilized.

1.4.5 Surface Soil Sampling and Analysis Plan

Technical Memorandum No. 5, *Surface Soil Sampling and Analysis Plan*, was submitted as an addendum to the Work Plan (DOE, 1992a). Although the Work Plan identified the determination of the extent of RAD contamination in surface soils due to wind dispersion as a specific objective of the RI, it did not provide for surface soil sampling. Therefore, the surface soil sampling plan was prepared in response to this data need.

Technical Memorandum No. 5 is divided into three sections. Section 1 presents results of prior surface soil programs at OU1, Section 2 is the formal sampling and analysis plan, and Section 3 describes quality assurance/quality control (QA/QC) considerations.

Based on a review of site history and previous geochemical investigations, a site-specific chemical analysis roster was developed for surface soils at OU1. This roster included RADs, metals, SVOCs, pesticides, and PCBs. VOCs were not included on the roster because they volatilize readily and because they are relatively mobile in soil and water, which makes their appearance in surface soils unlikely. The RADs, SVOCs, pesticides, and PCBs selected for the site-specific chemical analysis roster were previously detected in OU1 soils. All EPA priority pollutant metals were included in the roster. Manganese and iron were added to the list of metals at the request of CDH.

The plan required that OU1 surface soil data be validated before the data could be applied to toxicological interpretation in the BRA. To meet the documentation needs of the validation process, all surface soil data were analyzed at Level IV as defined by EPA (EPA, 1987a). RAD analyses of surficial soil samples were analyzed at DQO Level V.

To further ensure that the data collected met the needs of the BRA, the plan compared the detection limits for each analyte to relevant exposure limits. Exposure limits were computed for both an on-site ecological researcher and an on-site resident. Exposure limit values were different for these two hypothetical receptors because exposure limit computations considered likely exposure times. The crucial consideration was whether detection limits for a given analyte as specified in the *General Radiochemistry and Routine Analytical Services Protocol* (GRRASP) (EG&G, 1990c) were less than the calculated exposure limit values. If the calculated exposure limit was less than the GRRASP detection limit for a particular contaminant, then concentrations of that contaminant above the exposure limit could go undetected and the analyses not provide fully meaningful results for the BRA (EG&G, 1990c).

Exposure limit values calculated for an on-site ecological researcher were greater than the detection limits for all site-specific chemical analysis roster analytes. Exposure limit values for an on-site resident, however, were less than GRRASP detection limits for five roster analytes (antimony, beryllium, thallium, benzo(a)pyrene, and benzo(b)fluoranthene). While recognizing that the risk assessment objectives for these contaminants would be slightly compromised, the memorandum asserted that health effects associated with these compounds could still be quantified within the acceptable range.

The goal of the proposed sampling plan was to collect data representative of both radioactive and nonradioactive contamination in OU1 surface soils. The proposed plan included both random and biased sample sets. The random sample set included composite samples taken from 24 polygons chosen at random from a 454-polygon grid covering all OU1-related IHSS locations and the area topographically downgradient to Woman Creek. Data from this random sampling were suitable for determination of statistical mean contamination levels in surface soils at OU1. The biased sample set consisted of four sample sites chosen specifically to investigate contamination related to IHSSs 106, 130, 119.1, and 119.2. Site history and previous analyses identified these IHSS locations as the most likely potential sources of surface soil contamination within OU1.

Surface soil sampling methods in the plan were based on the sample collection techniques described in Geotechnical SOP GT.08, *Surface Soil Sampling* (EG&G, 1991a). Laboratory analyses covered the site-specific chemical analysis roster analytes, following methods referenced in the GRRASP (EG&G, 1990c).

Additional data collected in conjunction with surface soil sampling at OU1 included: a background study of RFP surface soil geochemistry; the addition of three sediment sampling sites in Woman Creek downgradient of OU1; and an air sampling program aimed at determining the level of suspended particulates at OU1. Data collected from these additional activities further supplemented data collected under the Phase III RFI/RI Work Plan to meet the anticipated needs for the BRA.

1.4.6 Exposure Scenarios

Technical Memorandum No. 6 presents potential exposure scenarios related to contamination at OU1 (DOE, 1992c). Prepared as a preliminary report for the PHE, as stipulated in the Interagency Agreement, these exposure scenarios formed the basis for development of the BRA. Because these scenarios were prepared for the PHE, only risks to human health were considered. Potential impacts on nonhuman receptors were considered in a parallel analysis done as part of the EE portion of the BRA.

Revision 4.0 of Technical Memorandum No. 6 was submitted for EPA and CDH review in June 1992. Comments received in August 1992 included a request for consideration of direct exposure to groundwater in the future on-site residential land use scenario. The PHE, Appendix F of the Draft RFI/RI Report, considered a hypothetical inhalation scenario, but, through rigorous pathway analysis, did not evaluate a groundwater ingestion exposure pathway because the small amount of groundwater at OU1 near IHSS 119.1 was not considered exploitable, based on modeling and drawdown calculations (Appendices B and C of Attachment F2-2). Throughout numerous discussions, neither EPA nor CDH refuted the technical basis for determining that groundwater in the vicinities of IHSS 119.1 could not be exploited for residential use due to extremely low yield. This conclusion was widely accepted among groundwater experts. This pathway is considered in the Final PHE at the insistence of EPA and CDH. The following is a summary of the general approach of the exposure scenarios memorandum.

In Technical Memorandum No. 6, climate, geology, hydrology, and biota at RFP in general and at OU1 in particular were all reviewed as background information. Because the prevailing wind direction at RFP and drainage orientations at OU1 are from the north and west, the off-site receptor populations at greatest risk are those located south and east of the plant.

The memorandum included analyses of current and future land use and related human exposure scenarios. The four land use groups considered in the memorandum included current on-site, current off-site, future on-site, and future off-site land use. Human exposure potentials associated with various land use options were evaluated separately for each of these four groups. The potential land uses considered for each group included residential, commercial/industrial, recreational, ecological reserve, and agricultural.

The current and future likelihood of each potential land use, both on- and off-site, was evaluated in the memorandum. Table 1-6 lists the conclusions drawn from both local and federal planning documents. Land uses classified as "credible" were the most likely, "plausible" land uses were conceivable but not expected, and "improbable" land uses were considered unlikely.

Exposure pathways were fully quantified in the PHE for the most credible land uses described in the memorandum. Where there were several likely land use alternatives, exposure scenarios were quantified only for those land uses with the highest potential for human exposure. It was assumed that the potential risk associated with the quantified scenario would define the boundaries of the potential risk for all other likely scenarios. Although future on-site residential use is improbable, this scenario was considered at the request of EPA and CDH. Three cases considering groundwater ingestion from residential use were added to the Final PHE (all cases also included the inhalation pathway). The cases were 1) use of sitewide data and assumed unlimited groundwater, 2) use of data from 119.1, where groundwater is assumed to be unlimited (even though use is physically improbable), and 3) use of data from 119.1, where the groundwater supply is limited, but is assumed to be supplemented by another water source, augmenting the OU1 groundwater in the area by a factor of 10. Potential exposure pathways to the current on-site industrial worker were also evaluated at the request of EPA and CDH.

The land use scenarios selected for quantitative exposure assessment included the following:

- Current off-site residential
- Current on-site commercial/industrial
- Future on-site residential
- Future on-site commercial/industrial
- Future on-site ecological reserve

Exposure pathways were recognized as complete, and the corresponding exposure parameters were identified for each of these five scenarios. The exposure parameters identified were used in the PHE portion of the BRA to develop reasonable maximum exposure values.

1.4.7 Description of Models for the Public Health Evaluation

Technical Memorandum No. 7 (DOE, 1992e) describes the contaminant fate and transport models that were used to calculate the exposure to potential receptors identified in Technical Memorandum No. 6 (DOE, 1992c). It was prepared as a preliminary report for the PHE as required by the Interagency Agreement. Technical Memorandum No. 7 (Revision 2.0) was submitted for EPA and CDH review in July 1992. Comments received in August 1992 included a request for groundwater modeling. The following is a summary of Technical Memorandum No. 7.

A conceptual model of the site was provided that illustrated the relationship between sources, release mechanisms and rates; transport media and processes; fate of contaminants; and potential receptors. The primary means of contaminant migration in the upper hydrostratigraphic unit (UHSU) is by volatilization of organic compounds and subsequent upward migration as a gas in the unsaturated zone. Surface runoff water, through erosion, however, may also convey contaminants by overland flow, and fugitive dust may be episodically resuspended by wind erosion and transported to on- or off-site receptors. Pathways involving three transport media were modeled for the BRA: the unsaturated (or vadose) zone, surface runoff water, and air. Groundwater modeling is not employed because the available groundwater data suggest the groundwater pathway is not complete (by virtue of the French Drain) and has not been associated with any potential receptors. In a meeting between DOE and the regulatory agencies, it was agreed that contaminant transport modeling would not be necessary to achieve RFI/RI objectives. Rather, calculations including retardation factors and simplified transport equations would be used to assess the possible velocity and extent of contaminant migration. The theoretical results would be compared with the sampling data to gauge the accuracy of the procedure.

The following general criteria were considered in selecting the models:

- The selected model(s) should be able to adequately simulate site conditions.
- The selected model(s) should be able to satisfy the objectives of the study.
- The selected model(s) should be verified and reasonably well field-tested.
- The selected model(s) should be well documented, peer-reviewed, and available to the public.
- The selected model(s) should be practical and cost effective.

Based on these criteria, the following models were selected to simulate the migration of contaminants at OU1:

- The Jury (Jury et al., 1983) and Johnson (Johnson and Ettinger, 1991) models for soil gas transport of VOCs contained in the unsaturated zone and stagnant groundwater.

- The Universal Soil Loss Equation (Wischmeier and Smith, 1978) and associated equations for surface water transport in overland flow to the SID.

- MILDOS-AREA (Yuan et al., 1989) for atmospheric modeling of emissions from a source, transport in air, and deposition at receptor locations. The MILDOS-AREA code was selected over other common models due to the capability to model particulate emissions coupled to the joint frequency distributions of wind speed, direction, and stability. Many other features of MILDOS-AREA are similar to other common Gaussian dispersion models. MILDOS-AREA simulated concentrations were coupled with the plant uptake (root and foliar) models contained in the RESRAD code (Gilbert et al., 1989) and the consumption and occupancy factors (DOE, 1992b) to estimate concentrations in potential receptors.

The exposure parameters required to conduct modeling for the PHE were tabulated in Technical Memorandum No. 7. The assumptions, uncertainties, and limitations associated with the selected models were also included. The PHE conducted for the Phase III RFI/RI deviated from the Work Plan as described below.

- The Jury et al. (1983) model predicts concentrations of VOCs in ambient air in hypothetical future structures as a result of volatilization of VOCs arising from vadose zone soils. The Johnson and Ettinger (1991) model output is similar except that it uses groundwater as the source for VOCs in air. Because OU1 soil chemistry data revealed no VOC concentrations in excess of 2.0 milligrams per kilogram (mg/kg), and because this concentration would not make a significant contribution to VOCs in a hypothetical structure, the use of the Jury model was eliminated.

- For the case of contaminants in sediments, actual measured concentrations were used in place of modeled values. Therefore, the Universal Soil Loss Equation was not used for the PHE.

Some data for modeling were obtained from the French Drain investigation that occurred prior to the Phase III RFI/RI field investigation (EG&G 1992e). Phase III data will be used to select COCs and characterize source areas and pathways at OU1.

1.4.8 Contaminant Identification

Technical Memorandum No. 8 identified the COCs for the risk characterization at OU1 (DOE, 1992g). It was prepared as a preliminary report for the PHE as stipulated in the Interagency Agreement. Technical Memorandum No. 8 was submitted to EPA and CDH for review in September 1992. Most of the document was incorporated into the Draft RFI/RI Report. Based on EPA and CDH comments on the Draft RFI/RI Report, the methodology for identifying contaminants was changed. This section summarizes the contaminant identification memorandum and then presents the change in contaminant selection methodology used in this Final RFI/RI Report.

Data from the OU1 Phase I, II, and III field investigations, supplemental surface soil sampling program, and routine groundwater monitoring program were used to compile site-specific analyte lists for the media (groundwater, surface soils, surface water, and sediment) where contaminants have been analyzed and detected. These media are sources of OU1 contaminants and represent the means by which current and future populations could potentially be exposed, either directly or indirectly.

As described in Technical Memorandum No. 6, *Exposure Scenarios* (DOE, 1992c), potential receptors could be exposed to contaminants in groundwater that volatilize to soil gas and potentially enter breathing air in a hypothetical future on-site resident home. Groundwater data were used to compile a site-specific analyte list for the soil gas exposure pathway. Analytes were limited to VOCs and SVOCs from the TCL and VOCs analyzed by EPA Method 502.2.

All of the exposure scenarios included direct contact with contaminants in surface soils and airborne contaminants released from surface soils by wind erosion. Surface soil data were used to compile a site-specific analyte list for the surface soil exposure pathway. Analytes consisted of SVOCs, PCBs, pesticides from the TCL, metals from the TAL, and select RADs.

The site-specific analyte list for the surface soil exposure pathway was also used for identifying COCs in surface water and sediment. Surface water and sediment monitoring stations in the SID and Woman Creek are located outside OU1 and are potentially influenced by contaminants from other OUs. Therefore, data from these stations are not exclusively representative of hazardous substances present at OU1 that may have contributed to the transport pathways.

Once site-specific analyte lists were compiled, a screening process developed using *Risk Assessment Guidance for Superfund* (RAGS) (EPA, 1989b) that consisted of the following:

- Eliminating chemicals considered essential human nutrients such as calcium, magnesium, potassium, and sodium.
- Eliminating contaminants with a detection frequency less than 5%.
- Delineating hot spots, a step designed to retain contaminants with elevated concentrations that might otherwise be eliminated because of infrequent detection. Contaminants exhibiting elevated concentrations with respect to the central tendency (mean) concentration include 1,1-dichloroethene, 1,1,1-trichloroethane, acetone, carbon tetrachloride, tetrachloroethane, trichloroethene, and methylene chloride.
- Eliminating contaminants with concentrations statistically similar to site background concentrations. Statistical tests performed included the F-Test, Bartlett's Test of Homogeneity of Variance, and Mann-Whitney U (Wilcoxin Rank Sum) Test. Tests were limited to metal and RAD data from surface soils.
- Eliminating contaminants contributing less than 1% of the risk based on a toxicity screen.
- Evaluating mobility, persistence, and transformation products of contaminants that were eliminated in the screening process. If high mobility, persistent, or toxic transformation products were confirmed, professional judgment was used to retain these contaminants on the list of concern. Chemicals thus retained as COCs are the following: chloroform, methylene chloride, dichlorodifluoromethane, and trichloro-fluoromethane.

Nineteen COCs were identified using this screening process; dibenzofuran was 1 of the 19 COCs. The toxicity factor for dibenzofuran was changed during preparation of Technical Memorandum No. 9, *Toxicity Constants* (DOE, 1992h), and as a result, dibenzofuran was eliminated as a COC. Elimination of dibenzofuran allowed four PAHs to be retained as COCs including benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and dibenzo(a,h)anthracene. A total of 22 COCs were to be used in the PHE portion of the BRA They are listed below for the four media.

- Groundwater: 1,1-dichloroethene, total 1,2-dichloroethene, 1,1,1-trichloroethane, carbon tetrachloride, chloroform, dichlorodifluoromethane, methylene chloride, tetrachloroethane, trichloroethene, and trichlorofluoromethane.

- Surface soil: acenaphthene, Aroclor-1254, benzo(a)pyrene, fluoranthene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, fluorene, pyrene, americium-241, plutonium-239, and plutonium-240.

- Surface water: americium-241, plutonium-239, and plutonium-240.

- Sediment: acenaphthene, Aroclor-1254, benzo(a)pyrene, fluoranthene, fluorene, pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, americium-241, plutonium-239, and plutonium-240.

The list of COCs in the PHE of this Final RFI/RI Report is slightly different than that presented above because the methodology for selection of OU1 contaminants was modified in response to EPA and CDH comments on the Draft RFI/RI Report and the data sets are slightly different (refer to the discussion in Section 2). The modified approach was presented to EPA and CDH on July 13, 1993. In overview, the RFI/RI Report (Section 4) presents a complete list of contaminants by media, and this list is further refined to a list of COCs using toxicological criteria. The list of contaminants was established by comparing site analyte concentrations to background concentrations using statistical analysis of variance (ANOVA) and comparison to background tolerance intervals. Where differences between background and site analyte concentrations were noted, the site data were further evaluated by assessing spatial and temporal concentration distributions as well as an assessment of laboratory or field sampling introduced artifact to assess whether elevated concentrations on site actually represent contamination. The rationale for inclusion or exclusion of an analyte as a site contaminant was provided. This is presented in Appendix D.

1.4.9 Toxicity Constants

Technical Memorandum No. 9 identifies the human toxicity constants that are to be used in the PHE portion of the BRA (DOE, 1992h). The BRA is part of the Phase III RFI/RI at OU1. This memorandum was prepared as a preliminary report for the PHE as stipulated in the Interagency Agreement. Technical Memorandum No. 9 was submitted for EPA and CDH review in September 1992. The toxicity constants were developed according to procedures presented in the RAGS (EPA, 1989b) and using the EPA *Integrated Risk Information System* (IRIS) and *Health Effects Assessment Summary Tables* (HEASTs) (EPA, 1991a; 1992b; 1992c) as the primary information sources. The toxicity constants were integrated with chronic daily intakes in the risk characterization portion of the PHE to yield quantitative risk estimates.

The toxicity constants for the OU1 COCs identified in Technical Memorandum No. 8, *Contaminant Identification* (DOE, 1992g), included reference doses and associated uncertainty factors for noncarcinogens and cancer slope factors and weight-of-evidence classifications for carcinogens. Region VIII toxicologists recommend that cancer slope factors for PAHs be derived using the toxicity equivalency factor approach in the *New Interim Region IV Guidance* (EPA, 1992d). The RAD slope factors that have been determined by EPA are maximum likelihood estimates due to extrapolation of low dose risks from risks observed at higher doses using nonthreshold, linear dose-response relationships. The slope factors account for the distribution, retention, and decay of RADs and daughter products in the body, the amount of RAD transported into the bloodstream, the radiation dose delivered to specific organs and tissues, and the age and sex of exposed individuals. Although health risks are calculated differently for carcinogens and noncarcinogens, some COCs (e.g., carbon tetrachloride, tetrachloroethene, and trichloroethene) can have both properties. Toxicological profiles for each COC are presented in the PHE. References for toxicological benchmarks have not changed in the Final RFI/RI Report.

1.4.10 Soil Sampling for Geotechnical Analysis

Geotechnical data are required to support site characterization and pathway definition, and with total organic carbon (TOC), are important inputs to site-specific fate and transport models. In preparation for collecting geotechnical samples and TOC samples at OU1, addenda to the SOPs and the Work Plan were prepared in October 1991. This section discusses the geotechnical sampling addendum, and Section 1.4.11 discusses the TOC soil sampling addendum.

The SOP addendum on soil sampling for geotechnical analysis supplements Geotechnical SOP GT.02, *Drilling and Sampling Using Hollow Stem Auger Techniques* (EG&G, 1991a). The geotechnical sampling plan for OU1 was prepared in conjunction with the SOP addendum; it identified 10 sampling locations. During implementation, samples were collected from 11 boreholes, based on judgement calls in the field.

The geotechnical SOP addendum called for samples for permeameter testing to be taken by the same method used for VOC samples. The latter method used a 3-inch, stainless-steel liner known as a California sleeve. The geotechnical field sampling plan required geotechnical samples to be taken in the uppermost alluvium (within 4 feet of the surface), in the lowermost alluvium, and in the uppermost bedrock (within 4 feet of the contact). In addition, in bedrock borings, one sample was taken in the approximate interval selected for packer testing and well/piezometer screening. To expedite the analytical process, companion samples for sieve analysis were taken from material immediately above each California sleeve sample and placed into glass sample jars.

1.4.11 Soil Sampling for TOC Analysis

Total organic carbon analysis of soil samples was required because it is an important parameter in developing site-specific fate and transport models. Therefore, an SOP addendum and field sampling plan for TOC sampling were prepared in October 1991 in conjunction with the geotechnical SOP and Work Plan addendum discussed above. The SOP addendum supplemented guidelines in Geotechnical SOP GT.02, *Drilling and Sampling Using Hollow Stem Auger Techniques* (EG&G, 1991a). The field sampling plan identified 10 locations for sampling. During implementation, samples were collected from 11 boreholes, based on judgement calls in the field.

The SOP addendum called for composite samples to be taken at 6-foot intervals. The sample intervals required were similar to those for geotechnical sampling: uppermost alluvium (the top 6 feet), lowermost alluvium (directly above the bedrock contact), and uppermost bedrock (directly below the bedrock contact). In bedrock borings, a TOC composite was also required in the approximate interval selected for packer testing and well/piezometer screening. Only one alluvial sample was required if bedrock was encountered at 6 feet or less below the ground surface.

1.4.12 Hand-Auger Sampling

This section summarizes an SOP addendum prepared in October 1991 in preparation for hand-auger sampling activities at OU1. Hand-auger sampling was used in sample locations where it was unsafe or impractical to use a standard drilling rig.

The hand-auger SOP addendum presented specific guidelines for hand-auger sampling using both split-spoon and sludge sampler techniques. Ultimately, split-spoon methods were used at the two locations that were hand augered. The split-spoon sampler was 2 1/2 inches measured on the inside diameter (i.d.) and was 2 feet long. The addendum stipulated that the split-spoon be driven with a slide hammer in 1-foot increments until auger refusal or to a depth of 10 feet. Samples were taken in polybutyrate tubes placed inside the split-spoons before sampling. After each 1-foot interval was driven, the split-spoon was retrieved from the hole and the polybutyrate sleeve was removed, capped, taped, labeled, recorded, and placed in a cooler whose interior temperature was kept at 4 degrees Centigrade.

After sending the first set of samples for analysis, the laboratory informed field personnel that polybutyrate-tubed core samples were not acceptable for organics analysis. As a result, both locations were redrilled less than 5 feet from the original locations using split-spoon samplers equipped with standard 3-inch-long, stainless-steel sleeves used for VOC sampling.

Table 1-1

Phase III RFI/RI Objectives, Proposed Work, and Completed Work (Page 1 of 6)

Objective	Proposed Work	Completed Work
Characterize Site Physical Features		
(1) Determine the extent of saturation and groundwater flow directions for the unconfined flow system both spatially and temporally.	• Install additional monitoring wells and piezometers. • Maintain and utilize the Rocky Flats Environmental Database System (RFEDS) for water level data from which potentiometric surface maps, saturated thickness maps, cross sections, and hydrographs can be prepared.	• Installed 23 new UHSU wells, 3 new LHSU wells, 4 new UHSU piezometers, and 1 new LHSU piezometers. • All new geologic and hydrologic data were input to the RFEDS database, which was then utilized to select an integrated data subset for preparation of maps and cross sections used to refine the Operable Unit No. 1 (OU1) hydrogeologic model (Section 3.7).
(2) Describe the interaction between the surface water and groundwater pathways.	• Compare water levels and water quality data from surface water sampling locations and groundwater.	• The interaction of surface water and groundwater was described utilizing an integrated data set taken from surface water and groundwater monitoring locations (Section 3.4).
(3) Quantify material properties.	• Perform aquifer tests to develop hydraulic conductivity and storage coefficient values for surficial materials.	• Aquifer tests were performed or attempted at the following locations: packer tests at 37891, 37991, 39191, and 39291; slug injection/slug withdrawal tests at 31891, 34791, 35691, 37191, 37891, 38191, and 39291; bail down/recovery tests at 36191, 37591, 37791, 37991, 38591, 38991 and 39191; pumping tests and tracer tests at 39891 and at 15-wellpoint array at Test Site # 1 (Section 3.7).
(4) Describe all soils and rock materials.	• Implement field logging program utilizing Standard Operating Procedures (SOPs).	• Soils and rock materials recovered at 114 drilling locations were logged according to the SOPs (Section 3.6).
(5) Verify the hydrogeologic site conceptual model for OU1.	• Integrate sitewide geologic and geophysical studies with hydrogeologic data from OU1.	• Geologic and hydrogeologic findings from sitewide geologic mapping, drilling, geophysics, french drain geologic mapping, and adjoining Operable Unit No. 2 (OU2) studies were integrated with OU1 data to refine the conceptual model (Section 3.7)

Table 1-1

Phase III RFI/RI Objectives, Proposed Work, and Completed Work (Page 2 of 6)

Objective	Proposed Work	Completed Work
Characterize Contaminant Sources		
(6) Characterize the nature and distribution of waste materials remaining on site.	• Collect samples from boreholes drilled directly through individual hazardous substance sites (IHSSs) where possible. Collect waste samples as well as soil samples from beneath the wastes. Analyze samples for Target Compound List (TCL) volatiles, semivolatiles, pesticides/polychlorinated biphenyls (PCBs), metals and inorganics, and radionuclides	• Four-hundred-nineteen soil samples were collected from soil boreholes as well as from monitoring well boreholes. Additional samples were taken from the effluent of the Building 881 footing drain and a drum of Coherex. Any recognizable waste materials were sampled according to the SOPs, along with the underlying soils. Analyses were completed according to the chemical analysis plan (Technical Memorandum No. 1). Boreholes were within or as close as possible to all designated IHSSs as well as in intervening areas. Figure 2-1 depicts the locations of all Phase III stations used for data collection to IHSSs. Results were used to characterize wastes and underlying soils (Section 4.3, 4.9).
(7) Characterize soils beneath wastes as well as soils at sites where wastes have been removed as potential contaminant sources.	• See above.	• See above (Section 4.3, 4.9).
(8) Identify which sites or subareas of sites are sources of contaminants in groundwater.	• Install alluvial groundwater monitoring wells directly beneath sites to assess groundwater levels and quality. • Install alluvial groundwater monitoring wells directly upgradient and downgradient of each site to pinpoint the source of contaminants.	• Ten monitoring wells were installed in sites and IHSS (Figure 2-1). Samples were collected under the routine monitoring program and analyzed where groundwater was present. Data were used to identify sources of groundwater contamination (Sections 4.3, 4.9). • Three upgradient and eight downgradient alluvial monitoring wells were installed (Figure 2-1) relative to individual or groups of IHSSs. Also, two wells (one upgradient, one downgradient) were completed in subcropping sandstones. Wells were developed and samples were collected under the routine monitoring program and analyzed where groundwater was present. Data were used to locate sources of groundwater contamination and determine the extent of contamination.

Table 1-1

Phase III RFI/RI Objectives, Proposed Work, and Completed Work (Page 3 of 6)

Objective	Proposed Work	Completed Work
Characterize the Nature and Extent Of Contamination		
(9) Determine the horizontal and vertical extent of surface radionuclide soil contamination due to wind dispersion.	• Collect surface soil scrapes in the study area following Colorado Department of Health (CDH) sampling procedures and analyze for radionuclides. • Sample and analyze vertical soil profiles for radionuclides.	• Surface soil samples were collected as part of the OU2 Phase II RFI/RI investigation according to CDH procedures at 11 locations in OU1 and analyzed for radionuclides. Surface soil samples were collected according to Rocky Flats Plant (RFP) procedures at 28 locations (Technical Memorandum No. 5), and were analyzed for radionuclides and other contaminants (Section 4.4). • Samples were collected from vertical soil profiles at four locations and were analyzed for radionuclides as part of the OU2 Phase II RFI/RI field investigation.
(10) Determine the nature and extent of groundwater contamination in surficial (i.e., alluvial) materials.	• Install alluvial groundwater monitoring wells in surficial materials located between areas of known groundwater contamination and areas with no groundwater contamination to delineate the extent. Collect groundwater samples and analyze for TCL volatiles, semivolatiles, pesticides/PCBs, metals and inorganics, and radionuclides.	• See Objective 8, second bullet under the Completed Work column (Section 4.7).

Table 1-1

Phase III RFI/RI Objectives, Proposed Work, and Completed Work (Page 4 of 6)

Objective	Proposed Work	Completed Work
(11) Determine the location of the weathered and unweathered sandstone units and the extent of the associated contamination.	• Install bedrock monitoring wells in new boreholes in which sandstones are encountered, including boreholes that were initially planned for installation of alluvial wells, as well as selected boreholes planned specifically to seek sandstone. Produce east-west and north-south geologic and water level cross sections as data permit. Collect groundwater samples and analyze for TCL volatiles, semivolatiles, pesticides/PCBs, metals and inorganics, and radionuclides.	• Two new bedrock monitoring wells were installed in boreholes planned specifically to seek bedrock sandstone at locations 31891 and 39691. Sandstones were found at the bedrock contact and these wells are screened in the sandstone unit. Also,well 31491 is screened in colluvium and sandstone. Two new bedrock piezometers (38991 and 39291) were installed in bedrock boreholes planned specifically to seek sandstone; in one of these, sandstone was not encountered, but a piezometer was installed nevertheless. Wells were developed and samples were collected under the routine monitoring program and analyzed where groundwater was present. Data were used to determine the location of the weathered and unweathered sandstone units and the extent of the associated contamination (Sections 3.7, 4.7).
(12) Characterize surface water quality.	• Continue collection of surface water from existing monitoring stations on a quarterly basis. Establish sediment stations directly associated with OU1 as sediment availability permits. Analyze samples for TCL volatiles, metals and inorganics, and radionuclides. Analyze surface water samples for both dissolved and total metals and radionuclides to determine if constituents are suspended or dissolved. Continue routine flow rate measurements at surface water stations.	• Samples were collected from surface water stations under the routine monitoring program on a quarterly basis and in some cases, more frequently. Six new sediment stations (SED037, SED038, SED039, SED040, SED041, and SED042) were established downgradient of OU1 in the South Interceptor Ditch and Woman Creek. The surface water and sediment samples were analyzed according to the chemical analysis plan (Technical Memorandum No. 1). Routine flow measurements at surface water stations were continued. Data were used to characterize surface water quality (Section 4.6.1).

Table 1-1

Phase III RFI/RI Objectives, Proposed Work, and Completed Work (Page 5 of 6)

Objective	Proposed Work	Completed Work
(13) Characterize radionuclides in Woman Creek sediments.	• Continue collection of surface water and sediment from existing monitoring stations on a quarterly basis. Establish sediment stations directly associated with OU1 as sediment availability permits. Analyze samples for TCL volatiles, metals and inorganics, and radionuclides. Analyze surface water samples for both dissolved and total metals and radionuclides to determine whether constituents are suspended or dissolved. Continue routine flow rate measurements at surface water stations.	• See above (Section 4.6.2).
(14) Identify and implement data management procedures.	• Maintain the RFEDS for all data collected during the Phase III RFI/RI. Utilize this database system to evaluate resulting data.	• All data collected during the Phase III RFI/RI were input to the RFEDS database and then extracted for evaluation and assessment (Section 4.1).
(15) Collect data of sufficient quality to facilitate development of a site conceptual model and comparison to applicable or relevant and appropriate requirements (ARARs).	• Adhere to the Rocky Flats Plant Environmental Restoration (ER) Program Quality Assurance Project Plan (QAPjP), General Radiochemistry and Routine Analytical Services Protocol (GRRASP), and the site-specific Quality Assurance Addendum (QAA).	• The Phase III RFI/RI data collection effort at OU1 was implemented in accordance with the RFP ER Program QAPjP, GRRASP, and the QAA for OU1 resulting in data meeting data quality objectives. The data were used to refine the site conceptual model and to facilitate comparison to potential ARARs (Section 4.1).
<u>Provide a Baseline Risk Assessment</u>		
(16) Describe contaminant fate and transport.	• Use existing literature and field data to describe the physiochemical processes associated with site contaminants. Incorporate Phase III results into risk analysis.	• Contaminant fate and transport have been described using up-to-date literature and all field data. Phase III data have been used in the risk analysis.

Table 1-1

Phase III RFI/RI Objectives, Proposed Work, and Completed Work (Page 6 of 6)

Objective	Proposed Work	Completed Work
(17) Assess the threat to public health and the environment from the No Action remedial alternative.	• Prepare a baseline risk assessment as part of the RI data analysis based on Phase I, II, and III RI.	• A baseline risk assessment has been performed using Phase III data.

Table 1-2

Summary of Documents Pertaining to Investigations Performed at Rocky Flats Plant Operable Unit No. 1 (Page 1 of 3)

Title of Document	Author	Date
Public Health Risk Assessment, 881 Hillside Area (OU1), Technical Memorandum No. 9, Toxicity Constants, Department of Energy, Rocky Flats Plant, Golden Colorado	DOE	September 1992
Public Health Evaluation, 881 Hillside Area (OU1), Technical Memorandum No. 8, Contaminant Identification, Department of Energy, Rocky Flats Plant, Golden, Colorado, Draft	DOE	September 1992
Description of Models for the Public Health Evaluation, Operable Unit One, Technical Memorandum No. 7, Department of Energy, Rocky Flats Plant, Golden, Colorado, Revision 2.0	DOE	July 1992
Public Health Risk Assessment, 881 Hillside Area (OU1), Technical Memorandum No. 6, Exposure Scenarios, Department of Energy, Rocky Flats Plant, Golden, Colorado, Revision 4.0	DOE	June 1992
Final Interim Measure/Interim Remedial Action French Drain Performance Monitoring Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	May 1992
Draft Final Technical Memorandum No. 5, Addendum to Final Phase III RFI/RI Work Plan, Surface Soil Sampling and Analysis Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	February 1992
Technical Memorandum No. 4, Addendum to the Final Phase III RFI/RI Work Plan, Tracer Test Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	November 1991
Technical Memorandum No. 3, Addendum to Final Phase III RFI/RI Work Plan, Multi-Well Pumping Test Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	November 1991
Draft Final Phase III RI/FS Environmental Evaluation Field Sampling Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	November 1991
Technical Memorandum No. 2, Responses to August 1, 1991 EPA Comments on the Operable Unit No. 1 RFI/RI Work Plan, Environmental Restoration, Program Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	August 1991

Table 1-2

Summary of Documents Pertaining to Investigations Performed at Rocky Flats Plant Operable Unit No. 1 (Page 2 of 3)

Title of Document	Author	Date
Technical Memorandum No. 1, Addendum to Final Phase III RFI/RI Work Plan, Chemical Analysis Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	August 1991
Quality Assurance Addendum (QAA 1.1) to the Rocky Flats Site-Wide Quality Assurance Project Plan for CERCLA RI/FS and RCRA RFI/CMS Activities for Operable Unit No. 1, 881 Hillside Area Phase III RFI/RI, Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	July 1991
Final Phase III RFI/RI Environmental Evaluation Work Plan, Rocky Flats Plant, 881 Hillside (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	June 1991
Final 881 Hillside Area Phase III Field Program (Operable Unit No. 1) Site Health and Safety Plan, EG&G Rocky Flats, Inc.	EG&G	April 1991
Final Phase III RFI/RI Work Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Department of Energy, (Revision 1), Rocky Flats Plant, Golden, Colorado	DOE	March 1991
Operable Unit No. 1 Interim Measure/Interim Remedial Action Implementation Document for Department of Energy, Rocky Flats Plant, Golden, Colorado	EG&G	February 1991
Response to EPA and CDH Comments on the Draft Phase III, RI/FS Work Plan 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	October 1990
Final Phase III RFI/RI Work Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Deparment of Energy, Rocky Flats Plant, Golden, Colorado	DOE	October 1990
French Drain Geotechnical Investigation, Department of Energy, Rocky Flats Plant, Golden, Colorado	EG&G	October 1990
Final Interim Measures/Interim Remedial Action Plan and Decision Document, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	January 1990

Table 1-2

Summary of Documents Pertaining to Investigations Performed at Rocky Flats Plant Operable Unit No. 1 (Page 3 of 3)

Title of Document	Author	Date
Final Environmental Assessment for 881 Hillside (High Priority Sites) Interim Remedial Action, Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	January 1990
Drawing No. 38548-127, General Site Plan and French Drain Re-Survey, Remedial Action, 881 Hillside Area, Rocky Flats Plant	Engineering-Science	1990
881 Hillside Remedial Investigation and Feasibility Study Response to EPA Comments	Rockwell	February 1989
Draft Feasibility Study Report for High Priority Sites (881 Hillside Area), Department of Energy, Rocky Flats Plant, Golden, Colorado	Rockwell	March 1988
Draft Final Remedial Investigation Report for High Priority Sites (881 Hillside Area), Department of Energy, Rocky Flats Plant, Golden, Colorado	Rockwell	March 1988

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CDH = Colorado Department of Health
CMS = Corrective Measure Study
EPA = Environmental Protection Agency
OU1 = Operable Unit No. 1
RCRA = Resource Conservation and Recovery Act
RFI/RI = RCRA Facility Investigation/Remedial Investigation
RI/FS = Remedial Investigation/Feasibility Study

Table 1-3

Summary of Phase III RFI/RI Work Plan Technical Memoranda and Standard Operating Procedure Addenda (Page 1 of 2)

Technical Memorandum/ SOP Addendum	Title of Document	Date
1	Addendum to the Final Phase III RFI/RI Work Plan, Chemical Analysis Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	August 1991
2	Responses to August 1, 1991 EPA Comments on the Operable Unit No. 1 RFI/RI Work Plan, Environmental Restoration Program, Department of Energy, Rocky Flats Plant, Golden, Colorado	August 1991
3	Addendum to the Final Phase III RFI/RI Work Plan, Multi-Well Pumping Test Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	November 1991
4	Addendum to the Final Phase III RFI/RI Work Plan, Tracer Test Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	November 1991
5	Addendum to the Final Phase III RFI/RI Work Plan, Surface Soil Sampling and Analysis Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado, Draft Final	February 1992
6	Public Health Risk Assessment, 881 Hillside Area (OU1), Exposure Scenarios, Department of Energy, Rocky Flats Plant, Golden, Colorado, Revision 4.0	June 1992
7	Description of Models for the Public Health Evaluation, Operable Unit One, Department of Energy Rocky Flats Plant, Golden, Colorado, Revision 2.0	July 1992

EMD = Environmental Management Department
EPA = Environmental Protection Agency
OU1 = Operable Unit No. 1
RFI/RI = RCRA Facility Investigation/Remedial Investigation
SOPA = Standard Operating Procedure Addendum
TOC = Total Organic Carbon

Table 1-3

Summary of Phase III RFI/RI Work Plan Technical Memoranda and Standard Operating Procedure Addenda (Page 2 of 2)

Technical Memorandum/ SOP Addendum	Title of Document	Date
8	Public Health Evaluation, 881 Hillside Area (OU1), Contaminant Identification, Department of Energy, Rocky Flats Plant, Golden, Colorado, Draft	September 1992
9	Public Health Risk Assessment, 881 Hillside Area (OU1), Toxicity Constants, Department of Energy, Rocky Flats Plant, Golden, Colorado	September 1992
Geotechnical	EMD Geotechnical SOPA, OU1 Soil Sampling for Geotechnical Testing Addendum, Rocky Flats Plant	October 1991
TOC	EMD Geotechnical SOPA, OU1 Soil Sampling for Total Organic Carbon Anaysis, Rocky Flats Plant	October 1991
Hand Auger	EMD Geotechnical SOPA, OU1 Hand Auger Sampling, Rocky Flats Plant	October 1991

EMD = Environmental Management Department
EPA = Environmental Protection Agency
OU1 = Operable Unit No. 1
RFI/RI = RCRA Facility Investigation/Remedial Investigation
SOPA = Standard Operating Procedure Addendum
TOC = Total Organic Carbon

Table 1-4

EPA/CDH Modifications to Chemical Analysis Plan for Phase III RFI/RI (Page 1 of 2)

IHSS Number	Borehole/ Well/SED Number	Workplan BH/MW/SED Designation	Proposed Chemical Analysis	EPA/CDH Modifications	Justification Provided for Modification
102	0887	0887	CLP VOA	EPA Method 502.2 VOA	Bedrock well downgradient from IHSS
107	39491	BH21	CLP VOA	All TCL organics	Not previously investigated
	0387	0387	CLP VOA	EPA Method 502.2 VOA	Previous sampling indicates contamination; only bedrock well downgradient from IHSS
119.1	0487	0487	CLP VOA	All TCL organics	Previous sampling indicates contamination
	4387	4387	CLP VOA	All TCL organics	Previous sampling indicates contamination
	0587	0587	CLP VOA	EPA Method 502.2 VOA	Only bedrock well in area of known contamination
	32791	MW25	CLP VOA	All TCL organics	Downgradient from known contamination
	33091	MW28	CLP VOA	All TCL organics	Downgradient from known contamination
	34891	BH27	CLP VOA	All TCL organics	Adjacent to well with known contamination
	33691	MW10	CLP VOA	All TCL organics	Not previously investigated
119.2	4587	4587	CLP VOA	EPA Method 502.2 VOA	Only bedrock well in IHSS
	33191	BH35	CLP VOA	All TCL organics	Not previously investigated
	32991	BH39	CLP VOA	All TCL organics	Not previously investigated
	34591	MW12	CLP VOA	All TCL organics	Not previously investigated
	34791	MW13	CLP VOA	All TCL organics	Not previously investigated
Woman	30091	BH54	CLP VOA	All TCL organics	Not previously investigated
Creek	SED 37	SED 37	CLP VOA	CLP VOA, pesticides/PCBs	Not previously investigated

BH = Borehole
CDH = Colorado Department of Health
CLP = Contract Laboratory Program
EPA = Environmental Protection Agency
IHSS = Individual Hazardous Substance Site
MW = Monitoring well
PCB = Polychlorinated biphenyls
SED = Sediment sampling station number
TCL = Target Compound List
VOA = Volatile organics analysis

Table 1-4

EPA/CDH Modifications to Chemical Analysis Plan for Phase III RFI/RI (Page 2 of 2)

IHSS Number	Borehole/ Well/SED Number	Workplan BH/MW/SED Designation	Proposed Chemical Analysis	EPA/CDH Modifications	Justification Provided for Modification
	SED 38	SED 38	CLP VOA	CLP VOA, pesticides/PCBs	Not previously investigated
	SED 39	SED 39	CLP VOA	CLP VOA, pesticides/PCBs	Not previously investigated

BH	=	Borehole	MW	=	Monitoring well
CDH	=	Colorado Department of Health	PCB	=	Polychlorinated biphenyls
CLP	=	Contract Laboratory Program	SED	=	Sediment sampling station number
EPA	=	Environmental Protection Agency	TCL	=	Target Compound List
IHSS	=	Individual Hazardous Substance Site	VOA	=	Volatile organics analysis

Table 1-5

Analytical Suite for Each Phase III Borehole and Monitoring Well (Page 1 of 4)

Borehole/Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides	Metals	Indicators
30091	BH54	X	X	X	X	X
30191	BH53	X	NA	X	X	X
30291	BH06	X	X	X	X	X
30391	BH52	X	NA	X	X	X
30491	BH52 offset	X	NA	X	X	X
30591	BH51	X	X	X	X	X
30691	BH09	X	X	X	X	X
30791	BH08/MW36	X	X	X	X	X
30891	BH07	X	X	X	X	X
30991	MW35	X	NA	NA	NA	NA
31091	BH05	X	X	X	X	X
31191	MW32	X	NA	NA	NA	NA
31291	BH05 offset	X	NA	X	X	X
31391	MW31	X	NA	NA	NA	NA
31491	MW30	X	NA	NA	NA	NA
31591	BH03	X	X	X	X	X
31691	BH05 offset	X	X	X	X	X
31791	MW36 offset	X	NA	NA	NA	NA
31891	BH04/MW02	X	X	X	X	X
31991	BH48	X	X	X	X	X
32091	BH18	X	X	X	X	X
32191	BH16	X	NA	X	X	X
32291	MW33	X	NA	NA	NA	NA
32391	BH49	X	X	X	X	X
32491	BH17	X	X	X	X	X
32591	MW24	X	NA	NA	NA	NA
32691	BH36	X	NA	X	X	X
32791	MW25	X	NA	NA	NA	NA
32891	BH38	X	NA	X	X	X
32991	BH39	X	X	X	X	X
33091	MW28	X	NA	NA	NA	NA

NA = Not Analyzed
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

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Table 1-5

Analytical Suite for Each Phase III Borehole and Monitoring Well (Page 2 of 4)

Borehole/Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides	Metals	Indicators
33191	BH35	X	X	X	X	X
33291	BH34	X	X	X	X	X
33391	MW27	X	NA	NA	NA	NA
33491	MW09	X	NA	NA	NA	NA
33591	BH37	X	X	X	X	X
33691	MW10	X	NA	NA	NA	NA
33791	BH33	X	NA	X	X	X
33891	MW08	X	NA	NA	NA	NA
33991	BH25	X	NA	X	X	X
34091	BH29	X	NA	X	X	X
34191	MW07	X	NA	NA	NA	NA
34291	BH28	X	X	X	X	X
34391	MW11	X	NA	NA	NA	NA
34491	BH24	X	NA	X	X	X
34591	MW12	X	NA	NA	NA	NA
34691	BH32	X	X	X	X	X
34791	MW13	X	NA	NA	NA	NA
34891	BH27	X	X	X	X	X
34991	BH31	X	NA	X	X	X
35091	MW26	X	NA	NA	NA	NA
35191	BH19/MW06	X	NA	X	X	X
35291	BH30	X	NA	X	X	X
35391	BH50/MW19	X	NA	X	X	X
35491	BH26	X	NA	X	X	X
35591	BH23	X	NA	X	X	X
35691	MW17	X	NA	NA	NA	NA
35791	BH43	X	NA	X	X	X
35891	BH40	X	NA	X	X	X
35991	MW18	X	NA	NA	NA	NA
36091	BH44	X	X	X	X	X
36191	MW05	X	NA	NA	NA	NA

NA = Not Analyzed
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

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Table 1-5

Analytical Suite for Each Phase III Borehole and Monitoring Well (Page 3 of 4)

Borehole/Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides	Metals	Indicators
36291	BH41	X	NA	X	X	X
36391	BH45/MW14	X	X	X	X	X
36491	BH01/MW01	X	X	X	X	X
36591	BH13	X	X	X	X	X
36691	BH46/MW15	X	NA	X	X	X
36791	BH12	X	X	X	X	X
36891	BH11	X	X	X	X	X
36991	BH10/MW04	X	X	X	X	X
37091	BH14	X	X	X	X	X
37191	BH47/MW16	X	X	X	X	X
37291	BH20	X	X	X	X	X
37391	BH02	X	X	X	X	X
37491	BH42	X	NA	X	X	X
37591	MW22	X	NA	NA	NA	NA
37691	MW23	X	NA	NA	NA	NA
37791	MW21	X	NA	NA	NA	NA
37891	MW27offset	X	NA	NA	NA	NA
37991	MW29	X	NA	NA	NA	NA
38091	MW20	X	NA	NA	NA	NA
38191	PZ05	X	NA	NA	NA	NA
38291	PZ06	X	NA	NA	NA	NA
38391	MW03	X	NA	NA	NA	NA
38491	MW03 offset	X	NA	NA	NA	NA
38591	MW34	X	NA	NA	NA	NA
38691	MW37	X	NA	NA	NA	NA
38791	MW37 offset	X	NA	NA	NA	NA
38891	PZ02	X	NA	NA	NA	NA
38991	PZ03	X	NA	NA	NA	NA
39091	PH01	X	NA	NA	NA	NA
39191	MW28 offset	X	NA	NA	NA	NA
39291	PZ01	X	NA	NA	NA	NA

NA = Not Analyzed
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

Table 1-5

Analytical Suite for Each Phase III Borehole and Monitoring Well (Page 4 of 4)

Borehole/Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides	Metals	Indicators
39391	PZ02	X	NA	NA	NA	NA
39491	BH21	X	X	X	X	X
39591	BH22	X	NA	X	X	X
39691	MW20 offset	X	NA	NA	NA	NA
39791	PH03	X	NA	NA	NA	NA
39891	Drive Point Hole	X	NA	NA	NA	NA

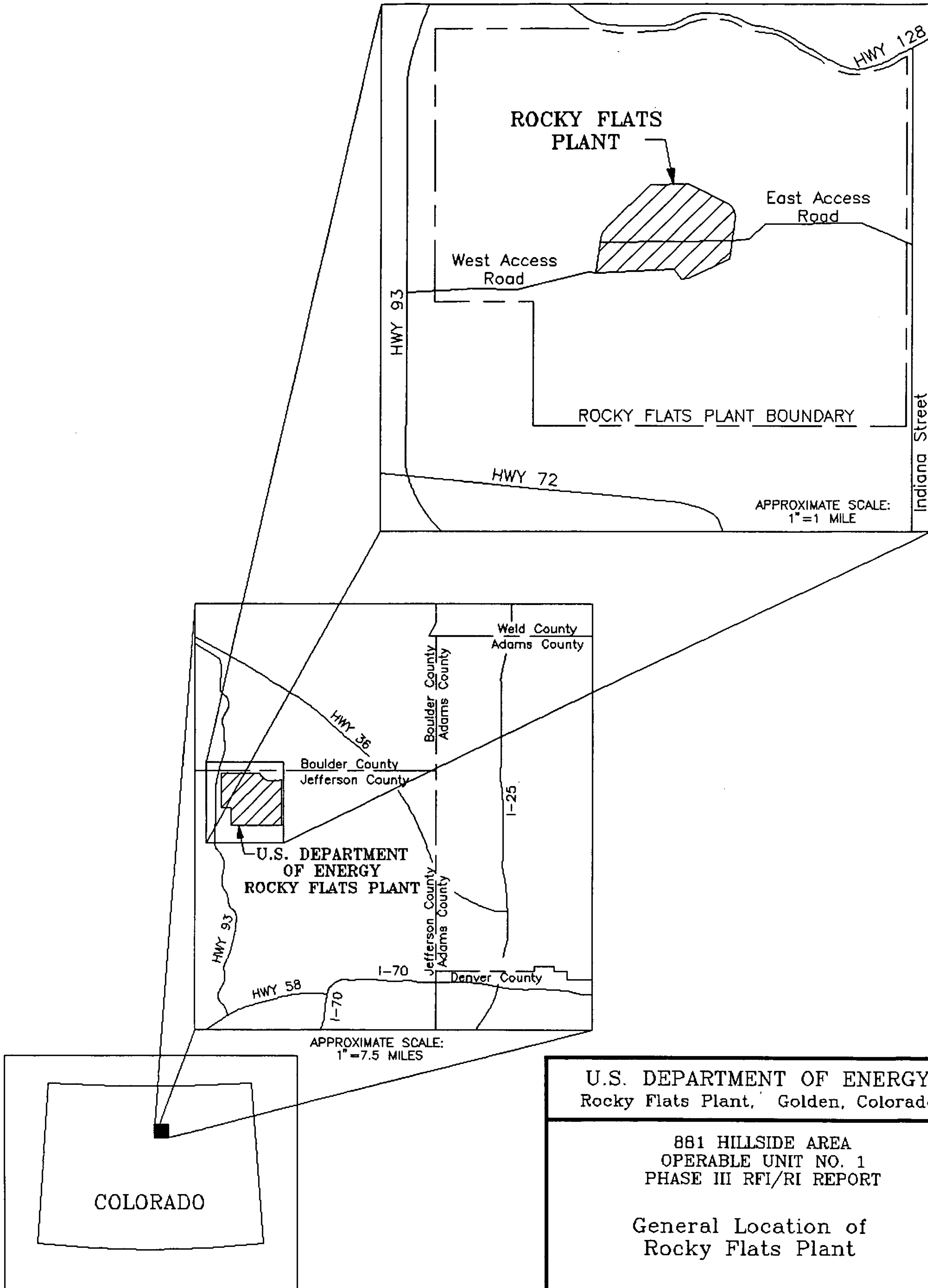
NA = Not Analyzed
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

Table 1-6

Analysis of Current and Future Land Use for Rocky Flats Plant Operable Unit No. 1* (Page 1 of 1)

	Current		Future	
Land Use Classification or Category	Off-Site	On-Site	Off-Site	On-Site
Residential	Yes	No	Credible	Improbable
Commercial/Industrial	Yes	Yes	Credible	Credible
Recreational	Yes	No	Credible	Plausible
Ecological Reserve	No	No	Improbable	Credible
Agricultural	Yes	No	Plausible	Improbable

* Land use possibilities are addressed in Technical Memorandum No. 6 (Revision 4.0). Supplementary scenarios have been included in the public health evaluation.



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

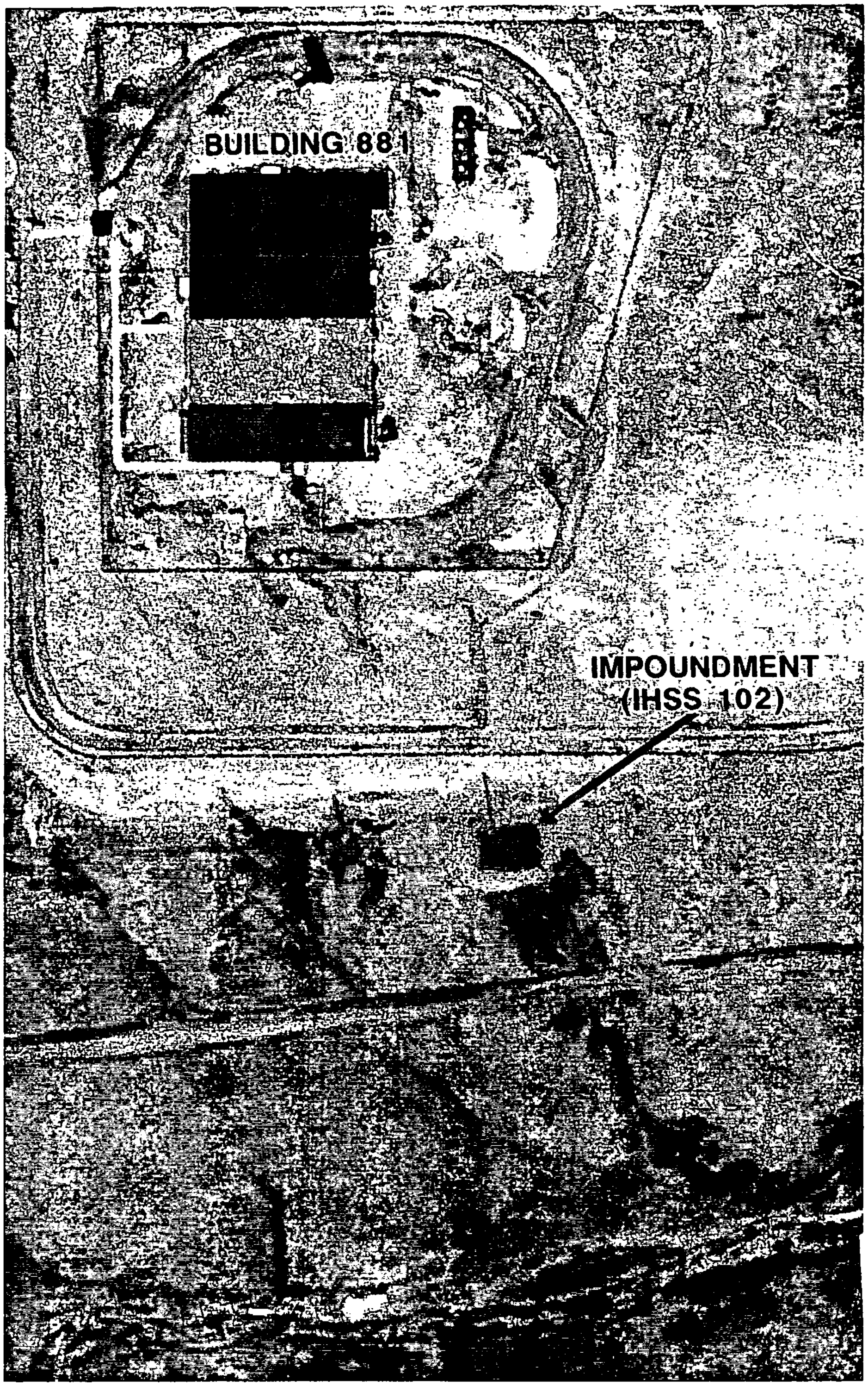
General Location of Rocky Flats Plant

Figure 1-1

REV. JULY 1993
OCTOBER 1992

R74056.PJ-072093

R74056.PJ-072093



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SCALE: 1" = 200'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

1955 Aerial Photo Showing
Location of IHSS 102

Figure 1-3

SEPTEMBER 1993

R74273.MD1022693

SECTION 2
OU1 FIELD INVESTIGATION

The OUI Phase III RFI/RI was an integrated investigation that was designed and implemented to address potential contamination in several media, and was focused to fill specific data gaps identified in previous investigations. This section of the report describes all components of the Phase III field investigation.

The four general objectives of the OU1 Phase III RFI/RI identified in the Work Plan (DOE, 1991b) were to characterize site physical features, contaminant sources, and nature and extent of contamination, and to provide a BRA. In order to achieve these objectives, the following types of investigations were performed at OU1:

- IHSS Investigations
- Air Quality and Meteorological Investigations
- Surface Water and Sediment Investigations
- Geological Investigations
- Surface Soils Investigations
- Groundwater Investigations
- Ecological Investigations
- Hot Spot Investigations

In general, the source characterization objective was addressed by the IHSS investigations; the site physical features and nature and extent of contamination were characterized as a part of the IHSS, surface water and sediment, geologic, and groundwater investigations; and the BRA is supported by data from all of the investigations, including the air quality and ecological investigations. Table 2-1 lists the various programs under which the investigations at OU1 were carried out. The subsections in Section 2 describe each of the investigations listed above.

2.1 DATA SETS

The Phase III RFI/RI Report presents all analytical data collected at OU1 from January 1990 through June 1992, with the exception of data that have been determined to be unacceptable (rejected during the data validation process). These data are presented in summary tables and are the data that were evaluated to determine contaminants at OU1. This data set is also used in the PHE and EE. Pre-1990 Phase I and II chemical data have been reviewed to confirm trends or note contradictions, and are presented in separate summary tables in the report. These data have been segregated from the more current data because the quality of the data is largely unknown. Data from the radiological screening survey that was completed in the Spring 1993 have also been evaluated and incorporated into the text. The Phase II data are not used in the PHE or the EE.

Hydrogeological interpretations presented in the final report utilized all available groundwater level data, and these data are presented in Appendix B. These data were used to construct potentiometric surface maps and to determine whether any hydrological trends were evident.

The sampling stations that are used in the Phase III Report are listed in Table 2-2. These include both Phase III and Phase I and II stations. Borehole logs for the borings and wells are included in Appendix A. The hydrological evaluation included data from locations that were not considered in the bulk of the RI Report. These are wells that were drilled as part of the background investigation or in conjunction with the investigations, either at OU2, and they appear only on the hydrological maps.

2.2 INDIVIDUAL HAZARDOUS SUBSTANCE SITE INVESTIGATIONS

The OU1 Phase III RFI/RI OU1 drilling program was conducted to provide a better definition of potential sources of contamination, site physical features, and the nature and extent of contamination present at OU1. Tables 2-3 and 2-4 present the locations, purpose, and completion details for boreholes and monitoring wells on an IHSS-by-IHSS basis. Figure 2-1 shows Phase III RFI/RI borehole and monitoring well locations.

Drilling locations were generally chosen relative to one or more of the 11 IHSS locations. For each IHSS, boreholes and/or monitoring wells were drilled within or near the IHSS for geologic characterization and definition of the nature and extent of contamination at each source. Boreholes were also drilled downgradient of various IHSSs, near the SID, and in the Woman Creek Valley Fill Alluvium to assess the nature and extent of soil contamination in areas downgradient of IHSSs. Monitoring wells were installed both upgradient and downgradient of OU1 IHSSs to isolate the impact of these IHSSs on groundwater quality. Finally, additional monitoring wells were installed along the SID and along Woman Creek in order to characterize groundwater quantity and quality in these downgradient areas, and to assess the interaction of the surface water and groundwater pathways.

Each drilling location specified in the Work Plan (DOE, 1991b) was designated a piezometer (indicated by a "PZ" designation), a borehole (indicated by a "BH" designation), a monitoring well (indicated by an "MW" designation), or a combination borehole and monitoring well. These designations, shown as "proposed numbers" in Tables 2-3 and 2-4, indicate the purpose of the drilling location and the drilling and completion details. It is important to note that because of conditions encountered at the site, drilling or completing wells in certain IHSS locations could not be performed. Therefore, a well may have been installed downgradient when the original purpose was to monitor the actual IHSS.

At borehole locations, the soil samples were used to characterize subsurface soils and to determine the nature and extent of soil contamination by sampling for an extensive suite of analytes. Following sample collection, the borehole was grouted to surface and the location was abandoned following procedures in Geotechnical SOP GT.05, *Plugging and Abandonment of Boreholes* (EG&G, 1991a). Locations with both borehole and monitoring well designations were sampled like other boreholes, then completed as monitoring wells. At both monitoring well and piezometer locations, soil samples were collected only at the water table and at the alluvium/bedrock contact. Both monitoring well and piezometer locations were cased and grouted. During the continued groundwater monitoring program the depth to groundwater was measured and aqueous samples were collected from the monitoring wells. Only the depth to water was measured at the piezometers during the routine monitoring.

Several locations originally proposed as monitoring wells were not completed because of shallow bedrock conditions. These locations were sampled as monitoring wells, i.e., at the water table (if it was present) and at the bedrock contact. Because they were not completed, these locations are designated as boreholes on all maps in this report. The locations are 31191, 31391, 32291, 32791, 33091, 33391, 34191, 34391, 35091, 38091, 38391, and offset 38491, 38691, and offset 38791. In addition, at three borehole/monitor well locations, 30791, 35191 and 36491 were not completed as wells.

In addition to the borehole, piezometer, and monitoring well locations, pilot holes (indicated by a "PH" designation) were drilled at potential multiple-well test sites, and wellpoints were installed at the single site used for the multiple-well test. Limited soil sampling was also performed in the pilot holes.

A total of 114 borings was drilled, including 95 borings for sampling and/or monitoring, 3 borings for pilot holes, and 16 borings for wellpoints. All 16 wellpoints were temporary installations. Twenty-six monitoring wells and 5 piezometers were installed at 31 of the monitoring locations. Following Geotechnical SOP GT.06, *Monitoring Wells and Piezometer Installation* (EG&G, 1991a), 96 of the 114 drilling locations were initially drilled using rig-mounted hollow-stem augers following Geotechnical SOP GT.02, *Drilling and Sampling Using Hollow Stem Auger Techniques* (EG&G, 1991a). The 16 wellpoint locations were drilled using rig-mounted solid augers, and the other 2 locations were drilled manually using a drive hammer. Appendix A1 provides details on the drilling locations and any deviations from the Work Plan. By agreement before field work began, offsets were designated as wells that could be completed within a 10-foot radius of the location specified in the Work Plan, and were necessary because of the field access problems. Because of the small size of certain IHSSs in OU1, it was felt that attempts located farther than this distance would not serve the original objective.

All borehole, piezometer, and monitoring well locations were drilled using 6-1/2-inch outside-diameter (o.d.) augers. Mechanically drilled boreholes along with bedrock piezometer and monitoring well locations were drilled approximately 3 feet into bedrock. Alluvial piezometer and monitoring well locations were drilled to the bedrock contact. Alluvial piezometer and monitoring well locations were then reamed with 11-5/8-inch o.d. augers. After reaming, alluvial boreholes were drive-sampled at least 2 more feet into bedrock to avoid smearing bedrock clays upward on the borehole walls. Bedrock boreholes were reamed with 14-inch o.d. augers. Wellpoint locations were drilled using 4-inch o.d. solid steel augers, with the stainless-steel wellpoints driven to total depth with a drive hammer.

Continuous core samples were taken during drilling using a 2-1/2-inch i.d. split-spoon sampler. Composite samples were collected at both borehole and monitoring well locations. Composite samples consisted of material peeled from the core recovered in each of three consecutive 2-foot drilling runs. The peeled material, typically 1/4 to 1/2 of the core, was homogenized in a bowl and then placed into sample containers such that the material in each sample container was representative of the entire 6-foot interval. For each composite sample a corresponding radiological screening sample was also collected from the material in the bowl. At monitoring well locations, each 6-foot composite sample consisted only of a radiological screening sample.

For VOC and geotechnical sampling, a stainless-steel sleeve was placed at the lead end of the split-spoon sampler. At borehole locations, VOC samples were taken at the base of the first 2-foot run and every 4 feet thereafter until either the water table or the bedrock contact was encountered. In addition, one VOC sample was collected directly below the water table, and one directly below the bedrock contact. At monitoring well locations, VOC samples were collected only at the water table and bedrock contact depths. For each VOC sample, a corresponding radiological screening sample was also collected at the same depth. Radiological screening samples were taken at all sampling locations to determine whether or not it was appropriate to ship samples off site for analysis.

Geotechnical and TOC samples were taken at 11 locations in OU1. While geotechnical samples were taken from discrete intervals, TOC samples were taken as composite samples from up to 6 feet of continuous core. All of the TOC samples were screened for the possibility of radiological contamination.

VOCs were the only compounds analyzed at monitoring well, piezometer, and pilot hole locations. Analyses of samples from borehole locations included VOCs, SVOCs, including acid and base/neutral extractables and pesticides/PCBs; RADs; metals; and inorganic compounds, including "indicator parameters." Table 2-5 presents the chemical analyses run on soil samples at each of the borehole, monitoring well, piezometer, and pilot hole locations. Some samples originally intended to be collected were not obtained, generally because of poor recovery. Sample collection is discussed in detail in Appendix A1. Table 2-6 presents the list of analytes for soil sample analyses.

As prescribed by the Work Plan, additional samples collected during the Phase III field investigation included samples of effluent from the Building 881 foundation drain as well as samples of Coherex, a dust suppressant previously used at OU1. Foundation drain effluent samples were collected by lowering a bailer down through a manhole access located approximately 150 feet south of Building 881. Coherex was sampled by pouring material directly from the storage drum into sample containers.

2.3 AIR QUALITY AND METEOROLOGICAL INVESTIGATIONS

Meteorological data collected for this report are based on the primary wind site at RFP, the 61-meter tower located in the west buffer zone. The tower is instrumented at 10, 25, and 60 meters to measure horizontal wind speed, vertical wind speed, wind direction, and temperature. Dew point measurements are made at the 10-meter level. Solar radiation measurements are taken by a radiometer mounted on an unobstructed platform at 1.5 meters above ground level. Ground level precipitation and pressure are also measured. Meteorological information in this report represents 96% data recovery from the 61-meter instrumentation.

Air monitoring programs have been conducted at RFP since the early 1950s. The plant currently incorporates air quality programs to protect the plant employees, the general public, and the environment through appropriate engineering, administrative controls, and subsequent monitoring and assessment of the impact to the air from both radiological and nonradiological sources. As part of this effort, a sitewide sampling program following Air SOP AP.13, *Radioactive Ambient Air Monitoring Program* (EG&G, 1991a), is ongoing to monitor for potential airborne dispersion of radioactive materials from RFP into the surrounding environment. This program consists of 51 RFP-designed, high-volume air samplers located throughout the plant site and the community. Data from this network are presented at monthly data exchange meetings held jointly with RFP, CDH, and representatives from the surrounding communities. In addition, an annual RFP site environmental report is published that includes all air monitoring data and associated impact analyses. The latest issue of this annual report is dated 1991 and covers the period from January through December 1990 (EG&G, 1991b).

Ambient air samplers that monitor airborne dispersion of radioactive particulates from OU1 include a combination of existing samplers from the RFP Radioactive Ambient Air Monitoring Program, and four special high-volume samplers set up specifically for this project following Air SOP AP.16, *Restoration Projects Radioactive Ambient Air Particulate Sampling High-Volume Methods* (EG&G, 1991a). Data used to document particulate dispersion from OU1 operations are from samplers S-9, S-10, S-11, S-17, S-23, S-38, S-39, and S-40 (Figure 2-2). Data from sampler S-32 are included to represent an upwind, background location. Ambient air samplers, designed at RFP, include a vortex-type, brushless motor that operates continuously at a volumetric flow rate of approximately 0.71 actual meters^3/minute, collecting air particulates on a 20- by 25-cm fiberglass filter. The four site-specific air samplers established for OU1 are commercially available units that use a patented critical flow device to hold the sampling flow rate at approximately 1.42 actual meters^3/minute. Figure 2-3 shows the location of these four high-volume samplers (S-81A, S-81B, S881C, and S-81D). Due to the continuous operation of the air sampler, it has been necessary to replace the carbon brush motors on a weekly basis to minimize sampler downtime. Filters for all OU1-related samplers were collected biweekly, composited by location, and analyzed monthly for plutonium. Section 4 presents the data from these samplers.

2.4 SURFACE WATER AND SEDIMENT INVESTIGATIONS

Surface water and sediment sampling are conducted on a monthly basis at RFP following Surface Water SOPs SW.01, *Surface Water Data Collection Activities*, SW.02, *Field Measurement of Surface Water Field Parameters*, and SW.03, *Surface Water Sampling* (EG&G, 1991a). Table 2-7 lists the chemical parameters for which sediment samples are analyzed, and Table 2-8 lists the chemical parameters for surface water samples. Analytical data retrieved from the Rocky Flats Environmental Database System (RFEDS) were used to describe the nature and extent of contamination in surface water and sediments in this report.

The RFI/RI includes data from 21 surface water stations (Figure 2-4). The list was expanded from that in the Phase III Work Plan to accommodate changes proposed by the regulatory agencies. Surface water stations SW036 and SW038 were proposed in the French Drain Monitoring Plan, and stations 125 and 126 were added based on the OU1 Quality Assurance Addendum to the Quality Assurance Project Plan for RFP. SW039 was added as the closest monitoring point in Woman Creek upgradient of OU1, and SW029 was added as a downgradient monitoring point in Woman Creek.

Two surface water stations were deleted from the list proposed in the Work Plan because of their distance from OU1: SW020, near the Solar Evaporation Ponds, and SW056, upgradient of OU1 on the SID. SW030 was deleted because other established stations were more specific to OU1.

The SID surface water is sampled at stations SW035, SW031, SW066, SW067, SW068, SW069, SW070, and upgradient locations SW036 and SW038. Woman Creek surface water is monitored by stations SW032, SW033, SW034, SW029, and upgradient location SW039. Surface water runoff from the 881 Hillside area flows into the SID and then into Pond C-2. Surface water in Woman Creek is routed around Pond C-2; however, water in Pond C-2 is discharged to Woman Creek in accordance with the plant National Pollutant Discharge Elimination System permit.

Station SW044 is located in the SID and previously monitored discharge from a pipe draining the skimming pond. Station SW045 monitored the foundation drain discharge from Building 881. This water flowed into the skimming pond but now discharges to the French Drain collection system. Station SW046 was located west of the skimming pond and monitored groundwater seepage from the skimming pond. The skimming pond was destroyed during excavation of the French Drain. Stations SW044, SW045, and SW046 are classified as seeps; however, stations SW045 and SW046 were eliminated during construction of the French Drain.

Several other seeps are present on the Hillside. These are monitored by stations SW071 and SW072 in IHSS 119.1, SW125 west of IHSS 130, and SW126 south of IHSS 102.

Eight sediment stations were sampled during the Phase III investigation: SED014, SED028, SED037, SED038, SED039, SED040, SED041, and SED042. Two bedload sediment sampling stations (SED037 and SED039) were established along the SID south of OU1 near surface water stations SW035 and SW070, respectively. Stations SED040, SED041, and SED042 were proposed in Technical Memorandum No. 5 and are located along Woman Creek. SED014 is an upgradient location on Woman Creek, and Station 028 is downgradient of OU1 on the SID. These stations replace the stations originally listed in the Phase III Work Plan, SED025-027 and SED029-031, which were downgradient of Pond C, and thus were influenced by OU2 as well as OU1. Station SED014, an upgradient station closer to OU1, replaced stations SED015 and SED018. Figure 2-5 shows the locations of the sediment sampling stations. The spatial distribution of the sediment stations has allowed characterization of sediment bedload contamination exclusively associated with OU1.

Because of freezing conditions and other factors affecting sediments, during each sampling event there were some stations that could not be sampled. Data for SED028 are available from June 1990 through August 1991. Samples were collected from stations SED037, SED038, and SED039 in November 1991. Attempts were made to collect samples from stations SED037, SED038, and SED039 in December 1991 and February 1992, but the sediment was frozen. Attempts were also made to collect samples in April 1992, but the stations did not have enough sediment. SED040, SED041, and SED042 were sampled only in February 1992. SED014, which is listed in Table 2-3 as an OU1 monitoring point, was last sampled in 1986.

2.5 GEOLOGICAL INVESTIGATIONS

Surface and subsurface geological investigations were conducted at OU1 as part of the Phase III RFI/RI site characterization. The general objectives of the geological investigation were to evaluate the influence of alluvial and bedrock geology on both the groundwater flow in the UHSU and on the release and movement of contaminants in the saturated zone. An additional goal was to obtain the geotechnical information needed for potential site remediation activities. The surface investigation included an analysis of pre-RFP historical aerial photographs to map the slumps and seeps observed during French Drain construction activities. The subsurface investigation included description and logging of alluvial and bedrock material from drill cores, borehole geophysics, sample collection for geotechnical analysis, and geologic mapping of the French Drain excavation.

Paired aerial photographs (1951, approximate scale 1"=750') were examined stereoscopically to locate seeps and to map slumps in the 881 Hillside area. Seeps were identified based on the nature and color of the vegetation in the photographs. Slumps were identified based on the presence of a curvilinear scarp or topographic break in slope at the top, a lobate shape, and hummocky topography at the base. Slump outlines were drawn based on these characteristics and were numbered using the numbering scheme developed in the geotechnical investigation (EG&G, 1990e). A map depicting slumps and seeps was constructed from the aerial photographs (refer to Section 3.6.3 of this report).

Subsurface geological investigations were conducted concurrently with the IHSS investigations, as discussed above in Section 2.2. Continuous core samples for geologic description were collected from the entire depth of 97 of the Phase III boreholes. The cores were described according to Geotechnical SOP GT.01, *Logging Alluvial and Bedrock Material* (EG&G, 1991a). Alluvium, colluvium, artificial fill, and soil were classified and described according to the Unified Soil Classification System. Weathered and unweathered bedrock materials were classified and described using the classification scheme developed by Compton (1962), which has been modified for use at RFP and is incorporated in the SOPs. Geologic borehole logs were input into the RFEDS using RFP well installation/borehole logging procedures.

Subsurface investigations also included borehole geophysics. Natural gamma logs and caliper logs were run in bedrock boreholes following Geotechnical SOP GT.15, *Geophysical Borehole Logging* (EG&G, 1991a), to select depth intervals for the packer tests. Natural gamma logs were used to determine relative clay content, and caliper logs were used to discern borehole diameter and depth intervals subject to caving. Appendix A1 includes the geophysical logs for boreholes 37891, 37991, 38991, 39191, and 39291.

Geotechnical samples were collected during drilling operations to determine physical properties of alluvial and bedrock material at OU1. Forty-six geotechnical samples were collected from 11 boreholes (37391, 37491, 37591, 37691, 37891, 37991, 38591, 38991, 39091, 39191, and 39691). Collection of samples followed procedures in the field sampling plan, which is summarized above in Section 1.3.10. Thirty alluvial and 16 bedrock samples were collected and sent out for analysis. Geotechnical analyses included grain-size distribution (mechanical sieve analysis and hydrometer tests), Atterberg limits including liquid and plastic limits and plasticity index, moisture content, density, back-pressure permeability, and specific gravity. Appendix A2 presents both raw test data and summary tables of geotechnical data for alluvial and bedrock materials.

The geology of the French Drain excavation was mapped using methods described in Geotechnical SOP GT.07, *Logging and Sampling of Test Pits and Trenches* (EG&G, 1991a). Lithologic contacts, particularly the alluvial/bedrock contact, were mapped at 25-foot transect intervals whenever construction activities of the French Drain permitted. Measuring tapes were placed at transect intervals and draped vertically along the excavation to determine unit thickness, depth to sample locations, and depth to bedrock contacts. Lithologic units were described using Geotechnical SOP GT.01, *Logging Alluvial and Bedrock Material* (EG&G, 1991a). Samples were collected from representative lithologic units for geotechnical analyses. *In situ* hydraulic conductivities were measured in bedrock according to Geotechnical SOP GT.23, *In Situ Hydraulic Conductivity Test* (EG&G, 1991a). Bedding attitudes, fault plane attitudes, slump glide plane attitudes, and joint and slickenside orientations were measured where possible with a Brunton compass. Seeps, zones of saturation, zones of permeability, and staining along joint surfaces were noted. The geology along the transect of the French Drain is discussed in detail in Appendix A4.

Subsequent to the completion of the Phase III field program, additional French Drain monitoring wells were installed to monitor the effectiveness of the French Drain (10092-11092, 39991, and 45391). Groundwater level data from these wells are discussed in Section 3.

2.6 SURFACE SOIL INVESTIGATIONS

Surface soil investigations were conducted at OU1 under two separate programs: RADs, and radioactive and nonradioactive contaminants. These programs are described below in Sections 2.6.1 and 2.6.2. Surface soil sampling for RADs was conducted from August 1991 to October 1992 as part of the Phase II RFI/RI for OU2 (DOE, 1991a) and included soil sampling locations in OU1. Surface soil sampling for radioactive and nonradioactive contaminants was conducted from February to March 1992 as part of the Phase III RFI/RI for OU1 (DOE, 1992a).

Data from these investigations have been used to determine the spatial and vertical extent of plutonium and americium in surficial soils, and to determine mean contaminant concentrations in surface soils for use in the BRA.

2.6.1 Surface Soil Sampling for RADs

Surface soil sampling was conducted in an area divided into 10- and 2.5-acre plots for the purpose of sampling for RADs in surface soils. The 2.5-acre grid was used in areas proximal to RAD contamination source areas in OU2 because the large variations in soil contaminant concentrations in these areas warrant a greater density of data. The 10-acre grid was used in distal areas where contaminant distribution is more uniform and, therefore, fewer data points were required. There were a total of eighty-five 10-acre plots and forty 2.5-acre plots; seven of the 10-acre plots and four of the 2.5-acre plots fall entirely or partially in the OU1 study area (Figure 2-6). Surface soils in all but one of the 10-acre plots and all but six of the 2.5-acre plots were sampled according to the CDH surface soil sampling protocol outlined in Geotechnical SOP GT.08, *Surface Soil Sampling* (EG&G, 1991a). The seven plots that were not sampled contained obstructions such as buildings or asphalt that made sampling impossible. All 11 of the plots in OU1 study area were sampled. However, Section 4.4 does not present all of these data, as some sampling locations were not appropriate because of distance from the IHSSs. In addition, some OU2 data are presented in Section 4.4 and discussed in regard to potential source area.

In accordance with the CDH sampling protocol, subsamples were collected on a uniform grid centered in the plot with a spacing of 132 feet for 10-acre plots and 66 feet for 2.5-acre plots. Twenty-five subsamples were collected within each 10- or 2.5-acre plot, each measuring 1/4 inch by 2 inches by 2-3/8 inches. These subsample grids were surveyed in the field using a tape and compass. Subsamples collected by the CDH method were composited into one sample per each plot.

2.6.2 Surface Soil Sampling for Nonradioactive and Radioactive Contaminants

The OU1 surface soil sampling and analysis program for nonradioactive and radioactive contaminants was specifically designed to collect data representative of surface soil contamination at OU1 that could be used to determine mean contaminant concentrations within an acceptable error of estimation. The goal of the program was to obtain data of high statistical quality to be used in the BRA. The study area covers the OU1 IHSSs and the area downslope to Woman Creek. This area was divided into more than four-hundred-fifty 50- by 100-foot contiguous rectangular plots, which were numbered sequentially. Twenty-four of the plots were selected for sampling with a random number generator. In addition, four biased sampling locations were selected in IHSSs 106, 130, 119.1, and 119.2. These four IHSSs are considered the most likely to have surface soil contamination because they are areas where contaminated liquids were suspected to have been discharged, where drummed wastes were stored, or where wastes were buried at shallow depths. A total of 28 of the 50- by 100-foot plots were sampled as shown in Figure 2-7. The sampling method used was a modification of the RFP method, described above in Section 2.5.1, where an array of 10 subsamples were collected in a local 3-square-meter area located at the geographic center of each plot. In this modification of the RFP method, 10 subsamples were collected in the center of the selected plots, and 10 subsamples were also taken at each corner of each selected plot using the same 3-square-meter configuration of subsample locations. The 50 subsamples thus collected were composited to create 1 sample for each of the 28 plots.

With EPA and CDH approval, a sampling program using a scheme identical to that described above was conducted in the Rock Creek area west and north of RFP to characterize background conditions. Soil types in the Rock Creek area parallel those at OU1, and the background soil samples were collected on a south-facing slope so that field conditions would be similar. As with OU1, the background area was divided into 50- by 100-foot rectangular plots that were sequentially numbered. Nine of the plots were selected for sampling with the random number generator. Figure 2-8 shows the locations of the nine plots sampled.

All samples taken at OU1 and in the Rock Creek area were analyzed for chemical parameters that included total metals, total RADs, and base/neutral extractable and pesticide/PCB SVOCs

(Table 2-9). In addition, approximately 20% of the samples (six OU1 samples and two background samples) were submitted for laboratory particle-size analysis (hydrometer test) and bulk-density testing.

2.7 GROUNDWATER INVESTIGATIONS

Groundwater sampling is conducted on a monthly basis at RFP following Groundwater SOP GW.01, *Water-Level Measurements in Wells and Piezometers*, GW.05, *Field Measurement of Ground Water Field Parameters*, and GW.06, *Ground Water Sampling* (EG&G, 1991a). All wells installed during the Phase III RFI/RI were developed and sampled during first quarter 1992. Table 2-10 lists the chemical parameters for which groundwater samples are analyzed. Four monitoring wells (0974, 1074, 0487, and 4387) were sampled for DNAPL in November 1991 during routine monitoring. Groundwater was collected using a clear bailer prior to well purging and was visually inspected for DNAPL liquids. DNAPL sampling and results are discussed in Section 4. Analytical data retrieved from the RFEDS were used to describe the nature and extent of contamination in groundwater in this report. As part of the site characterization work for OU1, single-well and borehole tests were conducted to develop hydraulic conductivity values for alluvial and bedrock materials. Figure 2-9 shows the locations of the single-well and borehole tests.

Packer tests were performed or attempted in the uncased portion of four bedrock boreholes (37891, 37991, 39191, and 39291). Although not specified in the Work Plan, test intervals were selected using natural gamma logs to determine bedrock lithology and using caliper logs to determine depth intervals subject to caving. Complications arising from poor weather conditions and nearby construction activities associated with the French Drain prevented the conduct of a packer test in borehole 38991 prior to well installation. In addition, borehole conditions allowed only one test, at 39191, to be completed within equipment performance standards. Table 2-11 presents information on the packer tests, and Appendix B1 provides a more thorough explanation of the tests and the results.

Two types of single-well tests (slug injection/slug withdrawal tests and bail down/recovery tests) were performed in Phase III monitoring wells and piezometers (Figure 2-9). Every monitoring well and piezometer with sufficient water level was tested, and available data on sustainable flow rates from surrounding older monitoring wells were used to predict results. Per the Work Plan, the type of test performed was dependent on the sustainable flow rate from a given well. Slug injection/slug withdrawal tests were performed in three alluvial monitoring wells (34791, 35691, and 37191), one alluvial piezometer (38191), two bedrock monitoring wells (31891 and 37891), and one bedrock piezometer (39291). Bail down/recovery tests were performed in four alluvial monitoring wells (36191, 37591, 37791, and 38591), two bedrock monitoring wells (37991 and 39191), and one bedrock piezometer (38991). Table 2-12 presents a summary of both types of aquifer tests, and Appendix B1 provides a more detailed description of the field operations and results.

A multiple-well pumping and tracer test program was conducted along Woman Creek downgradient of OU1 (Figure 2-10). The purpose was to collect data to better calculate estimates of solute travel times in saturated materials in the vicinity of the creek. Three test sites were specified in the Work Plan (DOE, 1991b), but only one site (Site #1) had a section of saturated alluvium thick enough to conduct the test.

Initially, a single temporary wellpoint (39891) was installed to a depth of 6 feet at Site #1. The wellpoint was used to conduct a step-drawdown pumping test to determine the optimum pumping rate for the multiple-well pumping test. This same wellpoint was then used to select the most appropriate tracer for the multiple-well tracer test. The test performance of distilled water was compared with potassium bromide and the latter was selected as most appropriate for the site conditions and test parameters. After completing the step-drawdown and tracer selection tests, 15 temporary wellpoints were installed, each to an approximate depth of 6 feet and 2.5 feet apart in an array of 3 rows of 5 wellpoints. This design was chosen to best produce a linear, sustainable flow field within a reasonable time period. Two multiple-well tests were conducted: a multiple-well pumping test provided data used to estimate transmissivity and specific yield, and a multiple-well tracer test provided data to determine effective porosity, linear dispersivity, and average groundwater flow velocity. At the conclusion of the multiple-well tests, all 16 wellpoints were removed and the boreholes were abandoned according to Geotechnical SOP GT.05, *Plugging and Abandonment of Boreholes* (EG&G, 1991a). Appendix B2 provides a more thorough explanation of the tests and the results.

2.8 ECOLOGICAL INVESTIGATIONS

Surveys of terrestrial and aquatic biota were conducted from April 1991 to February 1992 to characterize biological site conditions in terms of species presence, habitat characteristics, and community organization. Emphasis was placed on describing the structure of the biological communities within OU1 to identify the key species likely to be impacted by chemical contaminants. Once the chemical contaminants and key species were determined, the potential pathways and biotic receptors could be identified. Methods were developed in concert with the EE Work Plan (DOE, 1991c) and in compliance with Ecology SOPs (EG&G, 1991a). Details of the sampling program are contained in the EE Field Sampling Plan (DOE, 1991j).

Vegetation, wildlife, and aquatic organisms (plants and animals) can be exposed to contaminants directly through contact with contaminated media (air, soil, sediment, water). Animals can also be indirectly exposed through consumption of contaminated forage or prey (Figure 2-11). The conceptual model was developed to identify exposure pathways and exposure points. Each exposure pathway consists of four elements: source of contaminant, mechanism of retention or transport medium, an exposure route (e.g., ingestion), and a receptor (EPA, 1989a,b). These components can be further defined as involving primary or secondary sources and release mechanisms. A contaminant that has been released to the environment can be a contaminant source for other media. For example, soil contaminated by a spill could be a contaminant source for groundwater or surface water.

2.8.1 Synopsis of Exposure Pathways

The potentially most significant exposure pathways to biota COCs may be summarized as follows:

- Direct exposure of receptors to soil contaminants within OU1 IHSSs as well as outside the IHSS areas.
- Direct exposure of aquatic organisms to contaminants transported into surface water by wind, runoff, or shallow groundwater.

- Imbibition of contaminated surface water (including seeps and springs) by terrestrial vertebrates.

- Consumption of contaminated plant material by herbivores.

- Consumption of contaminated animal tissue by predators.

Data collected during the Phase III RFI/RI and ongoing RFP monitoring programs were used to evaluate exposure to contaminants in abiotic media. Evaluation of contaminant uptake by plants and animals was carried out by comparing tissue samples from OU1 with samples from areas upgradient of OU1 and from reference areas. For further information on exposure pathways refer to Section E6 of Appendix E.

2.8.2 Sampling and Testing Procedures

Biotic diversity and community composition reflect the health of an ecosystem. Species present in either terrestrial or aquatic ecosystems can indicate the degree of stress on a community due to perturbations as pollution-intolerant species are under represented in a stressed environment. The sampling program was designed to reflect environmental stress from comparisons between study and reference areas. Sampling for each ecological component was conducted in accordance with the Ecology SOPs. The primary objective was to collect data for comparison between reference and study area sites (Figures 2-12 and 2-13) that would reveal any adverse impacts in the study area.

Phytoplankton samples were collected during late summer 1991 from study and reference area ponds (Figure 2-14) in accordance with Ecology SOP EE.03, *Sampling of Plankton* (EG&G, 1991a). Periphyton were collected during late summer 1991. Artificial substrates (tiles and diatomers) were used as required in accordance with Ecology SOP EE.01, *Sampling of Periphyton* (EG&G, 1991a). Benthic macroinvertebrates were collected from streams and impoundments in accordance with Ecology SOP EE.02, *Sampling of Benthic Macroinvertebrates* (EG&G, 1991a). Collection of these organisms was conducted in May to June and August to September 1991. Study and reference area aquatic sites were evaluated for the likelihood that fish species were present. Fish were sampled in May to June and in August to September 1991 according to the most appropriate method as outlined in Ecology SOP EE.04, *Sampling of Fishes* (EG&G, 1991a).

Acute aquatic toxicity screens were conducted on samples collected from Woman Creek to ascertain gross toxicity of surface water and determine whether any toxicity detected could be a result of contaminants originating from the OU1 area. Samples were collected during low flow in August 1991 in accordance with Surface Water SOP SW.03, *Surface Water Sampling* (EG&G, 1991a), and the instructions and protocols from the toxicity testing laboratory. Samples were immediately placed in a cooler with "blue ice" and transported to the laboratory within 6 hours of collection. Toxicity tests commenced within 24 hours of collection and were conducted following to the techniques described in Peltier and Weber (1985) using fathead minnows and water-fleas as test organisms. These procedures are consistent with the CDH/Colorado and EPA Region VIII guidelines for biomonitoring. Hardness, alkalinity, conductivity, ammonia, pH, and dissolved oxygen were measured in samples prior to the toxicity tests. Other water chemistry data were obtained from results of RFP monthly surface water sampling activities.

Tissue samples were composed of plant and animal groups considered to be vulnerable components of the ecosystem (i.e., animals with small home ranges with intimate contact with the soil, plants, and aquatic organisms). Samples were taken from all sites where possible. Groups collected for tissue analysis of the terrestrial system included vascular plants, grasshoppers, small mammals, and reptiles. Specimens were collected from crayfish, salamanders, and fish for analysis of potential risk to the aquatic system. Procedures for collection and preparation followed the field sampling plan (DOE, 1991j) and the appropriate Ecology SOPs (EG&G, 1991a). The samples were analyzed for the constituents listed in Table 2-13.

2.8.3 Assessment of Ecological Risk

The evaluation of ecological risks associated with contamination at OU1 was carried out using the Hazard Quotient (HQ) method (EPA, 1989a,b). This method uses the ratio of the actual or estimated exposure concentrations to toxicologically based benchmark or reference values. The HQ method, or modified versions of it have also been applied in ecological risk assessments

(CDH, 1990 and EPA, 1989a; 1992e, 1992f). However, formal reference values are not readily available for most animal and plant species and must be derived from various sources.

2.8.4 Methodology for Soils, Surface Waters, and Sediments

Concentrations of COCs in soils collected during the Phase III field investigation were measured as total content per unit dry weight of soil. Data were collected for surface soils and soil borings to a maximum depth of 18 feet. Data from soil boring samples include gravel- and cobble-sized particles. This measure of soil content, which may be more properly termed geologic materials, probably overestimates the actual amount of metal that is bioavailable and, therefore, overestimates the potential toxicity.

The concentration of COCs in surface waters was evaluated from data collected during routine surface water monitoring RFP. Data from surface water stations upgradient and downgradient from OU1 IHSS areas were examined for exceedance of RFP background concentrations and surface water quality standards. Refer to Appendix E for data regarding dissolved and total recoverable metals in surface water samples. The dissolved measure represents that fraction most available to aquatic biota through respiratory and ingestion pathways and is most appropriate for comparison with Colorado Water Quality Standards.

Data on contaminant distribution in sediments are also drawn from routine monitoring conducted at RFP. Sediment sampling stations have been established on Woman Creek and the SID directly south of OU1, but no data were available for these sites. However, data were available for sites upgradient and downgradient from OU1. Sediment sampling stations SED016 and SED017 are located on Woman Creek west (upgradient) of OU1 and correspond to surface water stations SW107 and SW041, respectively. Sediment stations SED018 and SED019 are located at groundwater seeps and correspond to surface water stations SW080 and SW104, respectively. Station SED027 is located on Woman Creek just downstream from Pond C-1, and SED026 is located further downstream just above Pond C-2. Stations SED028 and SED031 are both on the SID, downgradient from OU1 but upgradient from Pond C-2. Data for sediments were expressed as total content per unit dry weight.

2.8.5 Quantification of Risks

The level of risk has been categorized as low, moderate, or high. A judgment of low risk indicates an exposure approximating the concentration at or below the threshold for toxic effects. Moderate risk is assessed for contaminant levels that indicate exposures exceeding the threshold for effects to sensitive species, but not exceeding the median lethal concentration for the population. Finally, high risk was determined to exist when exposures may affect more than half of the sensitive populations and may result in toxic effects to more tolerant species. Refer to Section E9 of Appendix E for further information on risk characterization.

Whole-body burdens of target analytes in plants and animals were measured for OU1 and reference area sites to determine gross concentrations of COCs. This measure does not assess the actual incorporation of target analytes into individual tissues, a measure needed to assess potential toxicity of accumulated contaminant loads, because nonavailable forms of COCs (e.g., minerals in soil ingested by organisms) were not quantified.

2.8.6 Taxonomic Group, Trophic Level, and Habitat Comparisons

Comparisons were made for species richness between OU1 and the Rock Creek reference area for terrestrial and aquatic taxonomic groups and trophic levels. Two computations were made for these comparisons: percentage and a chi-square statistic (Denenberg, 1976). The percentage was the amount each taxonomic group or trophic level in the food web contributed to total species richness for the area. The areas were then compared, looking for a difference between areas of more than 30%. Thirty percent is within the range of natural variability. If a difference greater than 30% occurred, a more detailed evaluation, including life history requirements for species, would be used to evaluate the variation in habitats at OU1 areas. This would entail making specific comparisons on the community level.

Organisms were classified by trophic level (i.e., producers, herbivores, etc.) to examine potential risks not found through analysis of groups identified through traditional taxonomic classification. The total number of species in each trophic level was calculated, and comparisons were made between numbers of species in each trophic level at the OU1 study area and the reference area. Endpoints for plants, arthropods, and small mammals included total number of taxa and species richness by taxonomic group. These endpoints were calculated from field data and tabulated using the mean, standard deviation, and standard error from the results of the four sample sites at OU1. Habitat comparisons were made by using the four sites in the OU1 study area and four sites in the Rock Creek watershed for similar habitats. Methods for the specific groups (i.e., vegetation sampling methods or small mammal sampling methods) are contained in the Ecology SOPs EE.06, *Sampling of Small Mammals*, and EE.10, *Sampling of Vegetation* (EG&G, 1991a).

2.9 HOT SPOT INVESTIGATION

A "hot spot" (area of elevated radioactivity) was discovered unexpectedly during a pre-job survey for the maintenance of the extraction well near well 0974 within IHSS 119.1. The "hot spot" dimensions were preliminarily determined to be roughly 10 inches in diameter by 12 inches deep with activities ranging from 10 nanoCuries per gram (nCi/g) (surface) to 50 pCi/g (at 1-foot depth)(Appendix A5). The area was posted and staked off in August 1992 to control access, and EG&G requested the agencies to approve emergency removal in November 1992.

Technical Memorandum No. 5, *Surface Soil Sampling and Analysis Plan* (DOE, 1992a), outlined a sampling strategy designed to estimate OU-wide surface soil RAD and non-RAD concentrations (Section 2.6). Although several sample locations were "biased" in IHSSs where surface RAD contamination was suspect, the strategy was not designed to detect the presence of localized "hot spots" of contamination. Thus, EG&G prepared a Supplemental Surficial Radiological Characterization Action Plan to evaluate whether other "hot spots" exist at OU1. The action plan, which is presented in Appendix A5, presented a two-part field characterization approach as follows:

- Part I: Characterizing the areal extent of the identified anomaly using a Field Gamma Spectroscopy System (FGSS) consisting of a truck-mounted High Purity Germanium (HPGe) Detector and characterization of the vertical extent through subsurface sampling and analysis.

- Part II: Conducting a quantitative and qualitative radiological survey (QQRS) to identify other "hot spots" using multiple field measurement techniques. These techniques included FGSS followed by walk-over Field Instrument for the Detection of Low Energy Radiation (FIDLER) surveys followed by portable gamma spectroscopy system (PGSS) surveys of identified areas of elevated activity.

This approach, as well as the details of the plan were reviewed and approved by EPA and CDH. Figure 2-15 exhibits the conceptual design of the characterization plan. Table 2-14 summarizes the actual events of the "hot spot" sample activities.

EG&G conducted preliminary characterization and comprehensive sampling of the originally identified "hot spot" on January 14 and 15, 1993. The original location is identified on Figure 2-16 as location SS100493. A PGSS was used to count each sample for radioactivity during the sampling activities. Using a shovel and trowel, soil was sampled at approximately 1/2-inch intervals. Samples for chemical analyses were collected at 0.75 inches, 4 to 5 inches, and 9 to 10 inches below ground surface. The sample hole was terminated at approximately 10 inches below ground surface due to sampling constraints from encountering a large rock. The samples were temporarily stored on-site pending determination of an appropriate laboratory to conduct the analyses.

The Supplemental and Surficial Radiological Characterization Action Plan Part I and II FGSS surveys were conducted in December 1992 and January 1993. Based on waste history for these IHSSs and as approved by EPA, CDH, and DOE, IHSSs 119.1, 119.2, and 130 were investigated. Each survey measurement covered a 75-foot radius (150 foot diameter), providing approximately 90% to 100% detection coverage. Each FGSS survey location with an integrated point source activity greater that 20 microcuries of americium-241 would be surveyed using the FIDLER. The results of the radiological operations gamma surveys are presented in Appendix A5. The FGSS survey identified nine anomalous areas, and a FIDLER survey was conducted to isolate and delineate potential anomalies identified by the FGSS survey

On January 28, 1993, a meeting was held between DOE, EPA, CDH, and EG&G to update EPA and CDH on progress toward characterizing the "hot spot." The minutes of the meeting are provided in Appendix A5. Discussions during the meeting included a detailed description of the results of the radiological field surveys to identify the presence of "hot spots." It was noted that nine "hot spot" areas within IHSSs 119.1 and 119.2 were potentially identified by the FGSS surveys. EPA and CDH were satisfied with the approach employed as described in the action plan.

The FIDLER survey was subsequently conducted in March and April 1993 to characterize the nine anomalous areas. Based on the survey, four "hot spot" locations were identified for soil sampling (Figure 2-16). The soil sampling was performed on April 29, 1993, by EG&G personnel with subcontractor support. The samples were collected using a hand shovel in accordance with the protocols described in SOP GT.8, *Surface Soil Sampling*. Each sample was screened using a PGSS. Samples were also collected using the CDH protocol that specifies the collection of surface scrapes to a depth of 1/4-inch below ground surface. Samples were then collected using a hand auger at depth until auger refusal. A summary of the samples collected, sample depth, and the analyses requested is provided in Table 2-15. It is noted that the samples originally collected from SS100493 were not submitted for organic analyses due to the lapse of time between collection and laboratory selection. Therefore, the location was resampled in April 1993 to collect samples for organic analysis. The results of the "hot spot" sample analyses are presented in Section 4.6.

Because the presence of "hot spots" is a significant element of the nature and extent of contamination, EPA and CDH agreed that the Final RFI/RI Report for OU1 be submitted in November 1993 rather than April 1993. This schedule extension provided the necessary time for sampling, chemical and radiological analysis, and evaluation and presentation of the "hot spot" investigation results.

Table 2-1

Investigative Programs at Operable Unit No. 1 (Page 1 of 1)

Type of Investigation	Program
Individual Hazardous Substance Site Investigations	Phase III RFI/RI Field Investigation
Air Quality and Meteorological Investigations	Routine Ambient Air Monitoring Program
Surface Water and Sediment Investigations	Routine Monitoring Program for Groundwater, Surface Water, and Sediments
Geological Investigations	Phase III RFI/RI Field Investigation
	French Drain Geologic Characterization Program
Surface Soils Investigation	Surface (Radionuclides) Soil Sampling and Analysis Program for OU1 and OU2 (conducted under the Phase II RFI/RI Field Investigation for OU2)
	Surface Soil Sampling and Analysis Program for OU1
Groundwater Investigations	Routine Monitoring Program for Groundwater, Surface Water, and Sediments
Ecological Investigations	Phase III Environmental Evaluation

RFI/RI = RCRA Facility Investigation/Remedial Investigation
OU1 = Operable Unit No. 1
OU2 = Operable Unit No. 2

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Table 2-2

OU1 Data Stations
Used in the Phase III RFI/RI Report

Boreholes	Wells	Surface Water	Sediment	Fr.Dr BH	Surface Soils
BH0187	0187	SW029	SED14[8]	B300190	RA010
BH0287	0287[1]	SW031	SED37	B300290	RA011
BH0387	0387BR[1]	SW032	SED38	B300390	RA012
BH0487	0487	SW033	SED39	B300490	RA013
BH0587	0587BR	SW034	SED40[4]	B300590	RA014
BH0687	0687[1]	SW035[3]	SED41[4]	B300690	RA015
BH0787	0887BR[1]	SW039[8]	SED42[4]	B300790	RA016
BH0887	0974[9]	SW044	SED28	B300890	RA017
BH0987	1074[9]	SW045		B300990	RA018
BH1087A	4387	SW046		B301090	RA019
BH1187	4487	SW066		B301190	RA020
BH1287A	4587BR	SW067		B301290	RA021
BH1387	4787	SW068		B301390	RA022
BH1487	4887	SW069		B301490	RA023
BH1587	4987	SW070		B301590	RA024
BH1687	5087	SW071		B301690	RA025
BH1787	5187	SW072		B301790	RA026
BH5787	5287	SW126[7]		B301890	RA027
BH5887	5387	SW036[8]		B301990	RA028
BH5987	5487	SW038[8]		B302090	RA029
BH6187	5587	SW125		B302190	RA030
BH6287	5787			B302290	RA031
BH6387	5886			B302990	RA032
	5986[1]			B303090	RA033
	5986R			B303190	RA034
30091	6286			B303290	RA035
30191	6386			B303390	RA036
30291	6486			B303490	RA037
30391	6886			B303590	
30491	6986[1]			B303690	
30591				B303790[2]	
30691	30991			B303890[2]	
30791	31491			B303990[2]	
30891				B304090[2]	
31091				B304190[2]	
31191				B304290[2]	
31291					
31391					

Table 2-2 (continued)

OU1 Data Stations
Used in the Phase III RFI/RI Report

Boreholes	Wells	Surface Water	Sediment	Fr.Dr BH	Surface Soils
	31791				
31591	31891				
31691	32591				
31891	33491				
31991	33691				
32091	33891				
32191	B302089[5]				
32291	B301889[5]				
32391	34591				
32491	34791				
32691	35391				
32791	35691				
32891	35991				
32991	36191				
33091	36391				
33191	36691				
33291	36991				
33391	37191				
33591	37591				
33791	37691				
33991	37791				
34091	37891				
34191	37991				
34291	38191[5]				
34391	38291[5]				
34491	38591				
34691	38891[5]				
34891	38991[5]				
34991	39191				
35091	39291[5]				
35191	39691				
35291	10092[6]				
35391	10192[6]				
35491	10292[6]				
35591	10392[6]				
35791	10492[6]				
35891	10592[6]				
36091	10692[6]				

Table 2-2 (continued)

OU1 Data Stations
Used in the Phase III RFI/RI Report

Boreholes	Wells	Surface Water	Sediment	Fr.Dr BH	Surface Soils
36291	10792[6]				
36391	10892[6]				
36491	10992[6]				
36591	11092[6]				
36691					
36791					
36891					
36991					
37091					
37191					
37291					
37391					
37491					
38091					
38391					
38491					
39091*					
39391*					
39491					
39591					
39791*					
39891**					

* Pilot holes
** Drive point hole
1 Well destroyed during construction of French Drain. Will use available data.
2 These borings were drilled for collection of geotechnical samples.
3 French Drain Monitoring Plan designated surface water stations.
4 Sediment stations proposed in Technical Memorandum 5.
5 Piezometers.
6 French Drain Monitoring Wells - do not use chemical data, only water level.
7 Received coordinates from RFEDS
8 Upgradient location.
9 Abandoned May 1992.

Table 2-3

Phase III RFI/RI Borehole Summary (Page 1 of 4)

IHSS Number	Borehole Number (Proposed Number)	Location	Purpose	Details: Borehole	Details: Total Depth (feet below ground surface)	Details: Alluvium/ Bedrock Contact (feet below ground surface)
102	36491 (BH01/MW01)	IHSS 102, Oil Sludge Pit Site	Characterize the nature and extent of contamination.	36491	18.6	14.0
	37391 (BH02)			37391	18.2	15.1
	31591 (BH03)	Within area of seepage from IHSS 102 identified on 1955 air photos	Characterize the nature and extent of contamination downgradient of IHSS 102; 31591 (BH03), 31091 (BH05), and 30291 (BH06) will also be used to evaluate the proposed french drain alignment.	31591	16.3	10.7
	31891 (BH04/MW02)			31891	21.6	17.2
	31091 (BH05)			31091	32.5	--
	31291 (BH05 offset)			31291	36.0	12.5
	31691 (BH05 offset)			31691	32.6	29.0
	30291 (BH06)	Downgradient of seepage area from IHSS 102	Characterize the nature and extent of contamination downgradient of IHSS 102	30291	22.9	15.5
	30891 (BH07)			30891	18.0	2.7
	30791 (BH08/MW36)	Vicinity of the former retention pond	Characterize the nature and extent of contamination within the site.	30791	18.7	9.5
	30691 (BH09)			30691	14.7	7.5
103	36991 (BH10/MW04)	IHSS 103, Chemical Burial Site; not previously drilled	Characterize the nature and extent of contamination within the site.	36991	11.3	8.0
	36891 (BH11)			36891	13.6	9.1
	36791 (BH12)			36791	16.3	12.5
104	36591 (BH13)	IHSS 104, Liquid Dumping Site; suspected to be mislocated from IHSS 103	Characterize the nature and extent of contamination to determine whether IHSS 104 has been mislocated.	36591	17.6	10.0
	37091 (BH14)			37091	8.6	4.1

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Alluvium/bedrock contact not encountered
est = Estimated

Table 2-3

Phase III RFI/RI Borehole Summary (Page 2 of 4)

IHSS Number	Borehole Number (Proposed Number)	Location	Purpose	Details: Borehole	Details: Total Depth (feet below ground surface)	Details: Alluvium/ Bedrock Contact (feet below ground surface)
105.1 and 105.2	(BH15)	IHSS 105.1 and 105.2, Out-of-Service Fuel Tank Sites	Characterize the nature and extent of contamination within the site.	Not Drilled		
	32191 (BH16)			32191	18.6	15.0
	32491 (BH17)			32491	10.9	6.0
	32091 (BH18)			32091	20.7	16.1
106	35191 (BH19/MW06)	IHSS 106, Outfall Site	Characterize the nature and extent of contamination in conjunction with a drainage test of Building 887 sump.	35191	6.3	2.0
	37291 (BH20)			37291	28.3	23.3
107	39491 (BH21)	IHSS 107, Hillside Oil Leak Site; boreholes to be within the skimming pond	Characterize nature and extent of contamination (using hand auger until refusal) in conjunction with effluent sampling from Building 885 footing drains.	39491	4.0	1.4
	39591 (BH22)			39591	3.0	--
119.1	35591 (BH23)	IHSS 119.1, Multiple Solvent Spill Site, within the Western Barrel Storage Area	Characterize the nature and extent of contamination within the site.	35591	6.3	2.3
	34491 (BH24)			34491	6.5	0.6
	33991 (BH25)			33991	12.6	2.4
	35491 (BH26)			35491	10.4	6.8
	34891 (BH27)			34891	14.6	11.0
	34291 (BH28)			34291	8.6	3.4
	34091 (BH29)			34091	10.3	6.2
	35291 (BH30)			35291	12.6	8.0
	34991 (BH31)			34991	16.3	12.3
	34691 (BH32)			34691	14.0	10.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Alluvium/bedrock contact not encountered
est = Estimated

Table 2-3

Phase III RFI/RI Borehole Summary (Page 3 of 4)

IHSS Number	Borehole Number (Proposed Number)	Location	Purpose	Details: Borehole	Details: Total Depth (feet below ground surface)	Details: Alluvium/ Bedrock Contact (feet below ground surface)
119.2	33791 (BH33)	IHSS 119.2, Multiple Solvent Spill Site, within the Eastern Barrel Storage Area	Characterize the nature and extent of contamination within the site.	33791	22.6	16.2
	33291 (BH34)			33291	14.8	10.0
	33191 (BH35)			33191	6.6	1.4
	32691 (BH36)			32691	8.6	3.3
	33591 (BH37)			33591	16.6	12.0
	32891 (BH38)			32891	8.8	4.0
	32991 (BH39)			32991	8.6	3.7
130	35891 (BH40)	IHSS 130, Radioactive Site - 800 Area Site #1, located within the site	Characterize the nature and extent of contamination within the site.	35891	12.6	8.0
	36291 (BH41)			36291	13.9	8.5
	37491 (BH42)			37491	16.0	12.0
	35791 (BH43)			35791	16.3	11.2
	36091 (BH44)			36091	18.6	14.3
	36391 (BH45/MW14)			36391	29.8	26.4
	36691 (BH46/MW15)			36691	28.3	25.0
	37191 (BH47/MW16)			37191	23.8	20.5
145	31991 (BH48)	IHSS 145, Sanitary Waste Line Leak, located within the site	Determine whether indications of possible contamination in nearby monitoring well 0187 are associated with the site.	31991	18.6	14.8
	32391 (BH49)			32391	12.9	4.2
177	35391 (BH50/MW19)	IHSS 177, Building 885 Drum Storage Site, downgradient of the site	Characterize the nature and extent of soil contamination downgradient from this site.	35391	12.0	6.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Alluvium/bedrock contact not encountered
est = Estimated

Table 2-3

Phase III RFI/RI Borehole Summary (Page 4 of 4)

IHSS Number	Borehole Number (Proposed Number)	Location	Purpose	Details: Borehole	Details: Total Depth (feet below ground surface)	Details: Alluvium/ Bedrock Contact (feet below ground surface)
South Interceptor Ditch	30591 (BH51)	Downgradient of the South Interceptor Ditch	Characterize the nature and extent of soil contamination downgradient of the South Interceptor Ditch.	30591	12.0	7.0
	30391 (BH52)			30391	32.5	28.0 (est.)
	30491 (BH52 offset)			30491	32.0	28.0
Woman Creek	30191 (BH53)	Along Woman Creek downgradient of OU1	Characterize the nature and extent of contamination in the valley-fill alluvium along Woman Creek.	30191	19.8	14.0
	30091 (BH54)			30091	13.9	8.1
	39091 (PH01)		Characterize soil and groundwater conditions of the multiple-well test sites.	39091	8.0	6.0
	39391 (PH02)			39391	10.0	7.0
	39791 (PH03)			39791	8.0	4.6
	39891 (Drive Point Hole)			39891	6.0	6.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Alluvium/bedrock contact not encountered
est = Estimated

Table 2-4

Phase III RFI/RI Monitoring Well and Piezometer Summary (Page 1 of 7)

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
102	(MW01)	IHSS 102, Oil Sludge Pit Site	Characterize colluvial groundwater beneath the site.	Not Installed	--	--
	31891 (BH04/MW02)	Area of seepage from IHSS 102	Characterize colluvial groundwater beneath the site.	31891	16.59-18.59	17.2
	31791 (MW36 offset)	Vicinity of former retention pond	Characterize Woman Creek valley-fill alluvial groundwater downgradient of IHSS 102.	31791	6.80-11.80	8.8
	38391 (MW03)			Abandoned	--	4.9-8.3 (est.)
	38491 (MW03 offset)			Abandoned	--	4.0
103	36991 (BH10/MW04)	IHSS 103, Chemical Burial Site	Characterize colluvial groundwater beneath the site.	36991	6.62-8.62	8.0
	36191 (MW05)	IHSS 103	Characterize colluvial groundwater immediately downgradient of IHSS 103.	36191	9.52-14.60	14.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-4

Phase III RFI/RI Monitoring Well and Piezometer Summary (Page 2 of 7)

				Completion Details		
IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Well/ Piezometer	Screened Interval (feet below ground surface)	Alluvium/ Bedrock Contact (feet below ground surface)
106	35191 (BH19/MW06)	IHSS 106, Outfall Site	Characterize colluvial groundwater beneath the outfall.	Abandoned	--	2.0
107	35691 (MW17)	IHSS 107, Hillside Oil Leak Site, within the skimming pond area	Characterize colluvial groundwater beneath the site.	35691	15.58-26.56	25.2
119.1	34191 (MW07)	IHSS 119.1, Multiple Solvent Spill Site, within and downgradient from the Western Barrel Storage Area	Characterize colluvial groundwater beneath and at the downgradient edge of the site.	Abandoned	--	4.0
	33891 (MW08)			33891	6.70-8.70	8.1
	33491 (MW09)			33491	6.68-8.69	8.0
	33691 (MW10)			33691	6.19-8.11	7.8
	34391 (MW11)			Abandoned	--	2.7
	3819 (PZ05)			38191	10-15	14.6

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-4

Phase III RFI/RI Monitoring Well and Piezometer Summary (Page 3 of 7)

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
119.2	34591 (MW12)	IHSS 119.2, Multiple Solvent Spill Site, at the downgradient edge of the site	Characterize alluvial groundwater at the sites east-southeast downgradient edge.	34591	6.90-8.90	8.2
	34791 (MW13)			34791	6.00-8.00	8.0
130	36391 (BH45/MW14)	IHSS 130, Radioactive Site - 800 Area Site #1 at the downgradient edge of the site	Characterize colluvial groundwater at the downgradient edge of the site.	36391	17.43-27.41	26.4
	36691 (BH46/MW15)			36691	15.83-25.83	25.0
	37191 (BH47/MW16)			37191	11.12-21.07	20.5
145	35991 (MW18)	Downgradient of IHSS 145, Sanitary Waste Line Leak	Characterize colluvial groundwater downgradient of the site.	35991	8.68-13.70	12.1
Down-gradient of 177	35391 (BH50/MW19)	Downgradient of IHSS 177, Building 885 Drum Storage Site, adjacent to 35391 (BH50)	Characterize colluvial groundwater downgradient of the site	35391	6.10-8.11	6.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-4

Phase III RFI/RI Monitoring Well and Piezometer Summary (Page 4 of 7)

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
Up-gradient of 119.1 and 119.2	38091 (MW20)	On the Rocky Flats Alluvium terrace north of IHSS 119.1 and IHSS 119.2	Characterize the upgradient alluvial groundwater at OU1.	Abandoned	--	--
	39691 (MW20 offset)			39691	7.00-9.00	6.8
	37791 (MW21)			37791	10.60-20.60	20.0
	37591 (MW22)			37591	7.60-12.60	12.0
	37691 (MW23)			37691	6.51-16.50	16.2
Down-gradient of 119.1	32591 (MW24)	Downgradient of IHSS 119.1, between wells 0974 and 0487	To further characterize the extent of volatile organics detected in wells 4887, 1074, 0974, and 0487. Wells 37591 (MW22) and 37691 (MW23) will also further delineate the extent of colluvial saturation and water quality in their locations.	32591	11.50-16.50	15.9

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-4

Phase III RFI/RI Monitoring Well and Piezometer Summary (Page 5 of 7)

				Completion Details		
IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Well/ Piezometer	Screened Interval (feet below ground surface)	Alluvium/ Bedrock Contact (feet below ground surface)
119.1 and 130	32791 (MW25)	In the vicinity of IHSS 119.1 and 130 in the sandstone screened by well 0587BR. MW27 presumably upgradient (west), MW28 presumably sidegradient (south), and MW29 presumably downgradient (east)	To further investigate elevated levels of total dissolved solids (TDS), strontium, and selenium detected in well 0587BR during 1989. Water levels will also be used to determine groundwater flow directions in the bedrock sandstone.	Abandoned	--	2.7
	35091 (MW26)			Abandoned	--	4.7
	33391 (MW27)			Abandoned	--	5.0
	37891 (MW27 offset)			37891	43.20-53.20	4.7
	33091 (MW28)			Abandoned	--	2.6
	39191 (MW28 offset)			39191	32.80-42.80	7.1
	37991 (MW29)			37991	45.20-55.20	6.9
South Interceptor Ditch	31491 (MW30)	Installed along the South Interceptor Ditch	Characterize colluvial groundwater adjacent to the South Interceptor Ditch. Data to be used to evaluate interactions between the ditch surface water and unconfined groundwater.	31491	13.90-18.90	16.5
	31391 (MW31)			Abandoned	--	2.5
	31191 (MW32)			Abandoned	--	4.7

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-4

Phase III RFI/RI Monitoring Well and Piezometer Summary (Page 6 of 7)

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
Woman Creek	32291 (MW33)	Along Woman Creek downgradient of the OU1 area	Used to further characterize valley-fill alluvial groundwater and surface water/groundwater interaction along Woman Creek downgradient of OU1.	Abandoned	--	4.1
	38591 (MW34)			38591	5.66-7.66	7.2
	30991 (MW35)			30991	5.10-9.90	9.0
	38691 (MW37)			Abandoned	--	7.4
	38791 (MW37 offset)			Abandoned	--	6.2
French Drain	39291 (PZ01)	Adjacent to wells 32591 (MW24) and 32791 (MW25)	Characterize the extent of weathered bedrock claystone saturation in weathered claystone upgradient of the french drain in conjunction with wells 32591 (MW24) and 32791 (MW25).	39291	33.95-43.95	10.7
	38891 (PZ02)	Downgradient of french drain	Characterize the extent of colluvial saturation downgradient of the french drain.	38891	7.30-9.30	9.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-4

Phase III RFI/RI Monitoring Well and Piezometer Summary (Page 7 of 7)

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
	38991 (PZ03)	Downgradient of french drain	Characterize the extent of weathered bedrock claystone saturation downgradient of the french drain.	38991	26.80-36.80	19.5
	(PZ04)	Downgradient of french drain	Characterize the extent of weathered bedrock claystone saturation downgradient of the french drain.	Not Installed	--	--
119.1	38191 (PZ05)	IHSS 119.1, in between boreholes 34991 (BH31) and 34691 (BH32)	Provide additional colluvial groundwater level data within IHSS 119.1.	38191	10.00-15.00	14.6
	38291 (PZ06)			38291	6.70-8.70	8.4

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-5

Soil Samples Collected During the Phase III RFI/RI Field Program for Chemical Analyses (Page 1 of 4)

Borehole/ Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides*	Metals+	Indicators**
30091	BH54	X	X	X	X	X
30191	BH53	X	X	X	X	X
30291	BH06	X	X	X	X	X
30391	BH52	X	X	X	X	X
30491	BH52 offset	X	X	X	X	X
30591	BH51	X	X	X	X	X
30691	BH09	X	X	X	X	X
30791	BH08/MW36	X	X	X	X	X
30891	BH07	X	X	X	X	X
30991	MW35	NA	NA	NA	NA	NA
31091	BH05	X	X	X	X	X
31191	MW32	NA	NA	NA	NA	NA
31291	BH05 offset	X	X	X	X	X
31391	MW31	X	NA	NA	NA	NA
31491	MW30	NA	NA	NA	NA	NA
31591	BH03	X	X	X	X	X
31691	BH05 offset	X	X	X	X	X
31791	MW36 offset	X	NA	NA	NA	NA
31891	BH04/MW02	X	X	X	X	X
31991	BH48	X	X	X	X	X
32091	BH18	X	X	X	X	X
32191	BH16	X	X	NA	X	X
32291	MW33	X	NA	NA	NA	NA
32391	BH49	X	X	X	X	X
32491	BH17	X	X	X	X	X
32591	MW24	X	NA	NA	NA	NA
32691	BH36	X	NA	X	X	X

X = Method analyzed
NA = Method not analyzed
VOCs = Volatile organic compounds analyzed by EPA CLP or EPA Method 502.2
SVOCs = Semivolatile organic compounds analyzed by EPA CLP BNA and EPA CLP pesticides/PCBs
CLP = Contract laboratory program
EPA = Environmental Protection Agency
BNA = Base/neutral/acid extractables
* = Gross alpha/beta, tritium, and radiochemical isotopes
+ = Metals analyzed by EPA CLP
** = Water quality parameters

Table 2-5

Soil Samples Collected During the Phase III RFI/RI Field Program for Chemical Analyses (Page 2 of 4)

Borehole/ Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides*	Metals+	Indicators**
32791	MW25	X	NA	NA	NA	NA
32891	BH38	X	NA	X	X	X
32991	BH39	X	X	X	X	X
33091	MW28	X	N/A	NA	NA	NA
33191	BH35	X	X	X	X	X
33291	BH34	X	X	X	X	X
33391	MW27	X	NA	NA	NA	NA
33491	MW09	X	NA	NA	NA	NA
33591	BH37	X	X	X	X	X
33691	MW10	NA	NA	NA	NA	NA
33791	BH33	X	NA	X	X	X
33891	MW08	X	NA	NA	NA	NA
33991	BH25	X	NA	X	X	X
34091	BH29	X	NA	X	X	X
34191	MW07	X	NA	NA	NA	NA
34291	BH28	X	X	X	X	X
34391	MW11	X	NA	NA	NA	NA
34491	BH24	X	NA	X	X	X
34591	MW12	X	NA	NA	NA	NA
34691	BH32	X	X	X	X	X
34791	MW13	NA	NA	NA	NA	NA
34891	BH27	X	X	X	X	X
34991	BH31	X	X	X	X	X
35091	MW26	X	NA	NA	NA	NA
35191	BH19/MW06	X	X	X	X	X
35291	BH30	X	NA	X	X	X
35391	BH50/MW19	X	NA	X	X	X

X = Method analyzed
NA = Method not analyzed
VOCs = Volatile organic compounds analyzed by EPA CLP or EPA Method 502.2
SVOCs = Semivolatile organic compounds analyzed by EPA CLP BNA and EPA CLP pesticides/PCBs
CLP = Contract laboratory program
EPA = Environmental Protection Agency
BNA = Base/neutral/acid extractables
* = Gross alpha/beta, tritium, and radiochemical isotopes
+ = Metals analyzed by EPA CLP
** = Water quality parameters

Table 2-5

Soil Samples Collected During the Phase III RFI/RI Field Program for Chemical Analyses (Page 3 of 4)

Borehole/ Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides*	Metals+	Indicators**
35491	BH26	X	NA	X	X	X
35591	BH23	X	NA	X	X	X
35691	MW17	X	NA	NA	NA	NA
35791	BH43	X	NA	X	X	X
35891	BH40	X	NA	X	X	X
35991	MW18	X	NA	NA	NA	NA
36091	BH44	X	X	X	X	X
36191	MW05	X	NA	NA	NA	NA
36291	BH41	X	NA	X	X	X
36391	BH45/MW14	X	X	X	X	X
36491	BH01/MW01	X	NA	X	X	X
36591	BH13	X	X	X	X	X
36691	BH46/MW15	X	NA	X	X	X
36791	BH12	X	X	X	X	X
36891	BH11	X	X	X	X	X
36991	BH10/MW04	X	NA	X	X	X
37091	BH14	X	X	X	X	X
37191	BH47/MW16	X	NA	X	X	X
37291	BH20	X	X	X	X	X
37391	BH02	X	X	X	X	X
37491	BH42	X	NA	X	X	X
37591	MW22	X	NA	NA	NA	NA
37691	MW23	X	NA	NA	NA	NA
37791	MW21	X	NA	NA	NA	NA
37891	MW27offset	X	NA	NA	NA	NA
37991	MW29	X	NA	NA	NA	NA
38091	MW20	NA	NA	NA	NA	NA

X = Method analyzed
NA = Method not analyzed
VOCs = Volatile organic compounds analyzed by EPA CLP or EPA Method 502.2
SVOCs = Semivolatile organic compounds analyzed by EPA CLP BNA and EPA CLP pesticides/PCBs
CLP = Contract laboratory program
EPA = Environmental Protection Agency
BNA = Base/neutral/acid extractables
* = Gross alpha/beta, tritium, and radiochemical isotopes
\+ = Metals analyzed by EPA CLP
** = Water quality parameters

Table 2-5

Soil Samples Collected During the Phase III RFI/RI Field Program for Chemical Analyses (Page 4 of 4)

Borehole/ Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides*	Metals+	Indicators**
38191	PZ05	X	NA	NA	NA	NA
38291	PZ06	X	NA	NA	NA	NA
38391	MW03	X	NA	NA	NA	NA
38491	MW03 offset	X	NA	NA	NA	NA
38591	MW34	X	NA	NA	NA	NA
38691	MW37	X	NA	NA	NA	NA
38791	MW37 offset	X	NA	NA	NA	NA
38891	PZ02	X	NA	NA	NA	NA
38991	PZ03	X	NA	NA	NA	NA
39091	PH01	X	NA	NA	NA	NA
39191	MW28 offset	X	NA	NA	NA	NA
39291	PZ01	X	NA	NA	NA	NA
39391	PH02	NA	NA	NA	NA	NA
39491	BH21	X	X	X	X	X
39591	BH22	X	NA	X	X	NA
39691	MW20 offset	X	NA	NA	NA	NA
39791	PH03	X	NA	NA	NA	NA
39891	Drive Point Hole	NA	NA	NA	NA	NA

X = Method analyzed
NA = Method not analyzed
VOCs = Volatile organic compounds analyzed by EPA CLP or EPA Method 502.2
SVOCs = Semivolatile organic compounds analyzed by EPA CLP BNA and EPA CLP pesticides/PCBs
CLP = Contract laboratory program
EPA = Environmental Protection Agency
BNA = Base/neutral/acid extractables
* = Gross alpha/beta, tritium, and radiochemical isotopes
+ = Metals analyzed by EPA CLP
** = Water quality parameters

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Table 2-6

Chemical Parameters for Phase III Soil Samples (Page 1 of 2)

Volatile Organic Compounds (VOCs)

1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,2-Dichloroethane
1,2-Dichloroethene
1,2-Dichloropropane
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Dibromochloromethane
Ethylbenzene
Methylene chloride
Styrene
Tetrachloroethene
Toluene
Total xylenes
Trichloroethene
Vinyl acetate
Vinyl chloride
cis-1,2-Dichloroethene
trans-1,2-Dichloroethene
trans-1,3-Dichloropropene

Semivolatile Organic Compounds (SVOCs)

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethyphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methyphenol
2-Nitroaniline
2-Nitrophenol
3,3'-Dichlorobenzidine
3-Nitroaniline
4,4'-DDD
4,4'-DDE
4,4'-DDT
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Aldrin
Anthracene
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Chrysene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Dieldrin
Diethyl phthalate
Dimethyl phthalate
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin ketone
Fluoranthene
Fluorene
Heptachlor
Heptachlor epoxide

Table 2-6

Chemical Parameters for Phase III Soil Samples (Page 2 of 2)

Semivolatile Organic Compounds (SVOCs) continued

Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Methoxychlor
n-Nitroso-di-n-propylamine
n-Nitroso-diphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Americium-241
Cesium-137
Gross alpha - dissolved
Gross beta - dissolved
Plutonium-239,-240
Radium-226
Radium-228
Strontium-89,-90
Tritium
Uranium-233,-238,-239
Uranium-233,-234
Uranium-235
Uranium-235,-236

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

Total petroleum hydrocarbons
Total organic carbon
pH

Table 2-7

Chemical Parameters for Phase III Sediment Samples (Page 1 of 3)

Volatile Organic Compounds (VOCs)

1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,2-Dichloroethene
1,2-Dichloroethane
1,2-Dichloropropane
1,2-Dimethylbenezene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Dibromochloromethane
Ethylbenzene
Methylene chloride
Styrene
Tetrachloroethene
Toluene
Total xylenes
Trichloroethene
Vinyl acetate
Vinyl chloride
cis-1,3-Dichloropropene
trans-1,2-Dichloroethene
trans-1,3-Dichloropropene

Semivolatile Organic Compounds (SVOCs)

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,2-Dichloroethane
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethyphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloroethyl vinyl ether
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methyphenol
2-Nitroaniline
2-Nitrophenol
3,3'-Dichlorobenzidine
3-Nitroaniline
4,4'-DDD
4,4'-DDE
4,4'-DDT
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Aldrin
Anthracene
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260
Benzenamine
Benzidine
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Chlordane
Chrysene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Dieldrin
Diethyl phthalate
Dimethyl phthalate
Endosulfan I
Endosulfan II
Endosulfan sulfate

Table 2-7

Chemical Parameters for Phase III Sediment Samples (Page 2 of 3)

Semivolatile Organic Compounds (SVOCs), continued

Endrin
Endrin ketone
Fluoranthene
Fluorene
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Methoxychlor
n-Nitroso-di-n-propylamine
n-Nitrosodimethylamine
n-Nitrosodiphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Americium-241
Cesium-137
Gross alpha - dissolved
Gross alpha - particle radioactivity
Gross beta - dissolved
Gross beta -particle radioactivity
Gross gamma
Plutonium-238
Plutonium-239
Plutonium-239,-240
Radium-226
Radium-228
Strontium-89,-90
Strontium-90
Tritium
Uranium-233,-238,-239
Total uranium
Uranium-233,-234
Uranium-234
Uranium-235
Uranium-235,-236
Uranium-238

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

% Moisture
% Solids
Alkalinity
Ammonia
Bicarbonate
Bromide
Carbonate
Chloride
Cyanide
Dissolved oxygen
Fluoride
Hardness
Ignitability
Nitrate
Nitrate + Nitrite
Nitrite
Oil and grease
pH

Table 2-7

Chemical Parameters for Phase III Sediment Samples (Page 3 of 3)

Indicators, continued

Phosphate
Phosphorus
Specific conductivity
Sulfate
Sulfide
Total dissolved solids
Total organic carbon
Total suspended solids
Turbidity

Table 2-8

Chemical Parameters for Phase III Surface Water Samples (Page 1 of 2)

Volatile Organic Compounds (VOCs)	Semivolatile Organic Compounds (SVOCs)	
		AROCLOR-1016
		AROCLOR-1221
1,1,1-Trichloroethane		AROCLOR-1232
1,1,2,2-Tetrachloroethane	1,2,4-Trichlorobenzene	AROCLOR-1242
1,1,2-Trichloroethane	1,2-Dichlorobenzene	AROCLOR-1248
1,1-Dichloroethane	1,3-Dichlorobenzene	AROCLOR-1254
1,1-Dichloroethene	1,4-Dichlorobenzene	AROCLOR-1260
1,2-Dichloroethane	2,4,5-Trichlorophenol	Benzo(a)anthracene
1,2-Dichloroethene	2,4,6-Trichlorophenol	Benzo(a)pyrene
1,2-Dichloropropane	2,4-Dichlorophenol	Benzo(b)fluoranthene
2-Butanone	2,4-Dimethyphenol	Benzo(ghi)perylene
2-Hexanone	2,4-Dinitrophenol	Benzo(k)fluoranthene
4-Methyl-2-pentanone	2,4-Dinitrotoluene	Benzoic acid
Acetone	2,6-Dinitrotoluene	Benzyl alcohol
Benzene	2-Chloronaphthalene	Bis(2-chloroethoxy)methane
Bromodichloromethane	2-Chlorophenol	Bis(2-chloroethyl)ether
Bromoform	2-Methylnaphthalene	Bis(2-chloroisopropyl)ether
Bromomethane	2-Methyphenol	Bis(2-ethylhexyl)phthalate
Carbon disulfide	2-Nitroaniline	Butyl benzyl phthalate
Carbon tetrachloride	2-Nitrophenol	Chrysene
Chlorobenzene	3,3-Dichlorobenzidine	Di-n-butyl phthalate
Chloroethane	3-Nitroaniline	Di-n-octyl phthalate
Chloroform	4,4'-DDD	Dibenzo(a,h)anthracene
Chloromethane	4,4'-DDE	Dibenzofuran
Dibromochloromethane	4,4'-DDT	Dieldrin
Ethylbenzene	4,6-Dinitro-2-methylphenol	Diethyl phthalate
Methylene chloride	4-Bromophenyl phenyl ether	Dimethyl phthalate
Styrene	4-Chloro-3-methylphenol	Endosulfan I
Tetrachloroethene	4-Chloroaniline	Endosulfan II
Toluene	4-Chlorophenyl phenyl ether	Endosulfan sulfate
Total xylenes	4-Methylphenol	Endrin
Trichloroethene	4-Nitroaniline	Endrin ketone
Vinyl acetate	4-Nitrophenol	Fluoranthene
Vinyl chloride	Acenaphthene	Fluorene
cis-1,2-Dichloroethene	Acenaphthylene	Heptachlor
trans-1,3-Dichloropropene	Aldrin	Heptachlor epoxide
	Anthracene	

Table 2-8

Chemical Parameters for Phase III Surface Water Samples (Page 2 of 2)

Semivolatile Organic Compounds (SVOCs) continued

Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Methoxychlor
n-Nitroso-di-n-propylamine
n-Nitroso-diphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Cesium-137
Gross alpha - dissolved
Gross alpha - particle radioactivity
Gross beta - dissolved
Gross beta -particle radioactivity
Gross gamma
Plutonium-239
Plutonium-239,-240
Radium-226
Strontium-89
Strontium-89,-90
Strontium-90
Tritium
Uranium-233,-238,-239
Uranium-233,-234
Uranium-234
Uranium-235
Uranium-235,-236
Uranium-238

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Cobalt
Copper
Cyanide
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

Bicarbonate
Carbonate
Chloride
Dissolved organic carbon
Fluoride
Nitrite
Nitrate + Nitrite
Oil and grease
pH
Phosphate
Phosphorus
Silica
Nonvolatile suspended solids
Sulfate
Sulfide
Total dissolved solids
Total organic carbon
Total suspended solids

Table 2-9

Chemical Parameters for OU1 and Rock Creek Surface Soil Samples (Page 1 of 2)

Semivolatile Organic Compounts (SVOCs)

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethyphenol
2,4-Dimitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methyphenol
2-Nitroaniline
2-Nitrophenol
3,3'-Dichlorobenzidine
3-Nitroaniline
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Anthracene
Benzo(a)anthracene
Benzo (a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Chrysene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Diethyl phthalate
Dimethyl phthalate
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
n-Nitroso-di-n-propylamine
n-Nitroso-diphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
0-Fluorophenol
4,4'-DDD
4,4'-DDE
4,4'-DDT
Aldrin
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260
Dieldrin
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin ketone
Heptachlor
Heptachlor epoxide
Methoxychlor
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Americium-241
Gross alpha - dissolved
Gross beta - dissolved
Plutonium-239,-240
Radium-226
Radium-228
Uranium-233,-234
Uranium-235
Uranium-238

Metals

Aluminum
Antimony
Arsenic
Barium

Table 2-9

Chemical Parameters for OU1 and Rock Creek Surface Soil Samples (Page 2 of 2)

Metals , continued

Beryllium
Cadmium
Calcium
Cesium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

Percent solids
Ammonia
Bicarbonate as CaCO3
Carbonate
Nitrate+Nitrite
Oil and grease
Specific conductivity
Total organic carbon
pH

Table 2-10

Chemical Parameters for Phase III Groundwater Samples (Page 1 of 2)

Volatile Organic Compounds (VOCs)

1,1,1,2-Tetrachloroethane
1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,1-Dichloropropene
1,2,3-Trichlorobenzene
1,2,3-Trichloropropane
1,2-Dibromoethane
1,2-Dichloroethane
1,2-Dichloroethene
1,2-Dichloropropane
1,2-Dimethylbenzene
1,3-Dichloropropane
1,3-Dimethylbenzene
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
1,2,4-Trimethyl benzene
1,2,5-Trimethyl benzene
Bromobenzene
Bromochloromethane
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Dibromochloromethane
Dibromoethane
Dichlorodifluoromethane
Ethylbenzene
Methylene chloride
Styrene
1,2-Dibromo-3-chloropropane
Tetrachloroethene
Toluene
Total xylenes
Trichloroethene
Trichlorofluoromethane
Vinyl acetate
Vinyl chloride
cis-1,2-Dichloroethene
cis-1,2-Dichloropropene
n-Butylbenzene
n-Propylbenzene
o-Chlorotoluene
p-Chlorotoluene
p-Cymene
sec-Butylbenzene
tert-Butylbenzene
trans-1,2-Dichloroethene
trans-1,3-Dichloropropene

Semivolatile Organic Compounds (SVOCs)

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethyphenol
2,4-Dimitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methyphenol
2-Nitroaniline
2-Nitrophenol
3,3'-Dichlorobenzidine
3-Nitroaniline
4,4'-DDD
4,4'-DDE
4,4'-DDT
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Aldrin
Anthracene
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260
Benzo(a)anthracene
Benzo (a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether

Table 2-10

Chemical Parameters for Phase III Groundwater Samples (Page 2 of 2)

Semivolatile Organic Compounds (SVOC) continued

Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Chrysene
Cumene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Dieldrin
Diethyl phthalate
Dimethyl phthalate
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin ketone
Fluoranthene
Fluorene
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Methoxychlor
n-Nitroso-di-n-propylamine
n-Nitroso-diphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Americium-241
Cesium-137
Gross alpha - dissolved
Gross beta - dissolved
Plutonium-238
Plutonium-239,-240
Radium-226
Strontium-89,-90
Tritium
Uranium-233,-234
Uranium-235
Uranium-238

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

Alkalinity
Bicarbonate
Carbonate
Chloride
Cyanide
Fluoride
Nitrate
Nitrite
Nitrate + Nitrite
pH
Phosphate
Silica
Sulfate
Total dissolved solids
Total suspended solids

Table 2-11

Phase III RFI/RI Packer Test Information (Page 1 of 1)

Borehole Number	Water Level (feet)	Test Interval (feet)	Lithology
37891	40.50	37.20 - 56.30	Claystone, clayey siltstone, silty claystone, siltstone with trace clay and sand
		29.20 - 57.00	Claystone, clayey siltstone, silty claystone, siltstone with trace clay and sand
37991	Dry	42.10 - 51.90	Clayey siltstone, claystone, sandy clayey siltstone, silty claystone
		42.10 - 57.50	Clayey siltstone, claystone, sandy clayey siltstone, silty claystone
38991	No test due to hazardous access and poor weather conditions.		
39191	Dry	17.60 - 26.80	Claystone with varying amounts of silt
39291	43.17	43.20 - 47.60	Silty claystone

Note: Borehole conditions allowed only one test, at well 39191, to be completed within equipment performance standards.

Table 2-12

Phase III RFI/RI Single-Well Test Information (Page 1 of 2)

Well/Piezometer Number	Sand (BGS) (feet)	Screen (BGS) (feet)	Water Level for Test (feet)	Lithologic Zone*	Saturated Lithologies Tested	Selected Type of Test
31891	14.6-19.0	16.8-18.4	15.51	A, B	Alluvial sandy clay Bedrock clayey sandstone	Slug injection/slug withdrawal
34791	5.9-9.5	6.2-7.7	2.44	A	Silty sand, gravel	Slug injection/slug withdrawal
35691	13.4-28.96	15.8-26.4	9.34	A	Silty clay with some sand and gravel; sandy clay and clayey gravel	Slug injection/slug withdrawal
36191	7.4-14.9	9.7-14.4	11.94	A	Well graded gravelly sand with a 0.06 foot layer of clay	Bail down/recovery
37191	9.2-22.0	11.3-20.9	7.13	A	Gravelly, sandy clay	Slug injection/slug withdrawal
37591	5.6-14.6	7.8-12.4	11.19	A	Gravel, sand, and clay	Bail down/recovery
37791**	8.8-22.6	10.8-20.4	20.01	A	Clay with silt, sand, and gravel	Bail down/recovery
37891	40.0-55.2	43.4-53.0	41.90	B	Silty claystone, clayey siltstone; siltstone with clay, trace sand	Slug injection/slug withdrawal
37991	43.0-57.2	45.4-55.0	48.78	B	Claystone, sandy clayey siltstone	Bail down/recovery
38191	8.1-14.9	10.1-14.9	9.38	A	Sand, silt, and clay with gravels and silty gravelly sand	Slug injection/slug withdrawal
38591	5.0-8.0	5.9-7.5	6.50	A	Silty sand with clay and gravel	Bail down/recovery
38991	24.8-37.8	27.0-36.6	27.80	B	Claystone, siltstone with clay and sand, silty claystone and clayey siltstone	Bail down/recovery

BGS = Below Ground Surface

*A = Alluvial
B = Bedrock

Table 2-12

Phase III RFI/RI Single-Well Test Information (Page 2 of 2)

Well/Piezometer Number	Sand (BGS) (feet)	Screen (BGS) (feet)	Water Level for Test (feet)	Lithologic Zone*	Saturated Lithologies Tested	Selected Type of Test
39191	30.0-45.0	33.0-42.6	35.36	B	Clayey siltstone with organics; claystone with silt, siltstone with clay	Bail down/recovery
39291	31.7-45.9	34.2-43.8	30.25	B	Claystone, silty claystone, clayey siltstone	Slug injection/slug withdrawal

** Reliable results could not be obtained.

BGS = Below Ground Surface

*A = Alluvial
B = Bedrock

Table 2-13

Chemical Parameters for Biological Tissue Samples (Page 1 of 1)

Radionuclides	Metals
Americium-241 (Am-241)	Cadmium (Cd)
Plutonium-239,-240 (Pu-239,-240)	Chromium (Cr)
Plutonium-238 (Pu-238)	Copper (Cu)
Radium-226 (R-226)	Lead (Pb)
Total Uranium	Mercury (Hg)
	Selenium (Se)
	Silver (Ag)
	Zinc (Zn)

Table 2-14

"Hot Spot" History

Event	Date
Original "hot spot" identified	August 1992
HPGe Survey (identifies 9 areas in 119.1, 119.2, and 130)	December 1992 to January 1993
Sampling of original "hot spot"	January 1993
FIDLER Survey (identifies 4 "hot spots")	March to April 1993
"Hot spot" sampling	April 1993

Table 2-15

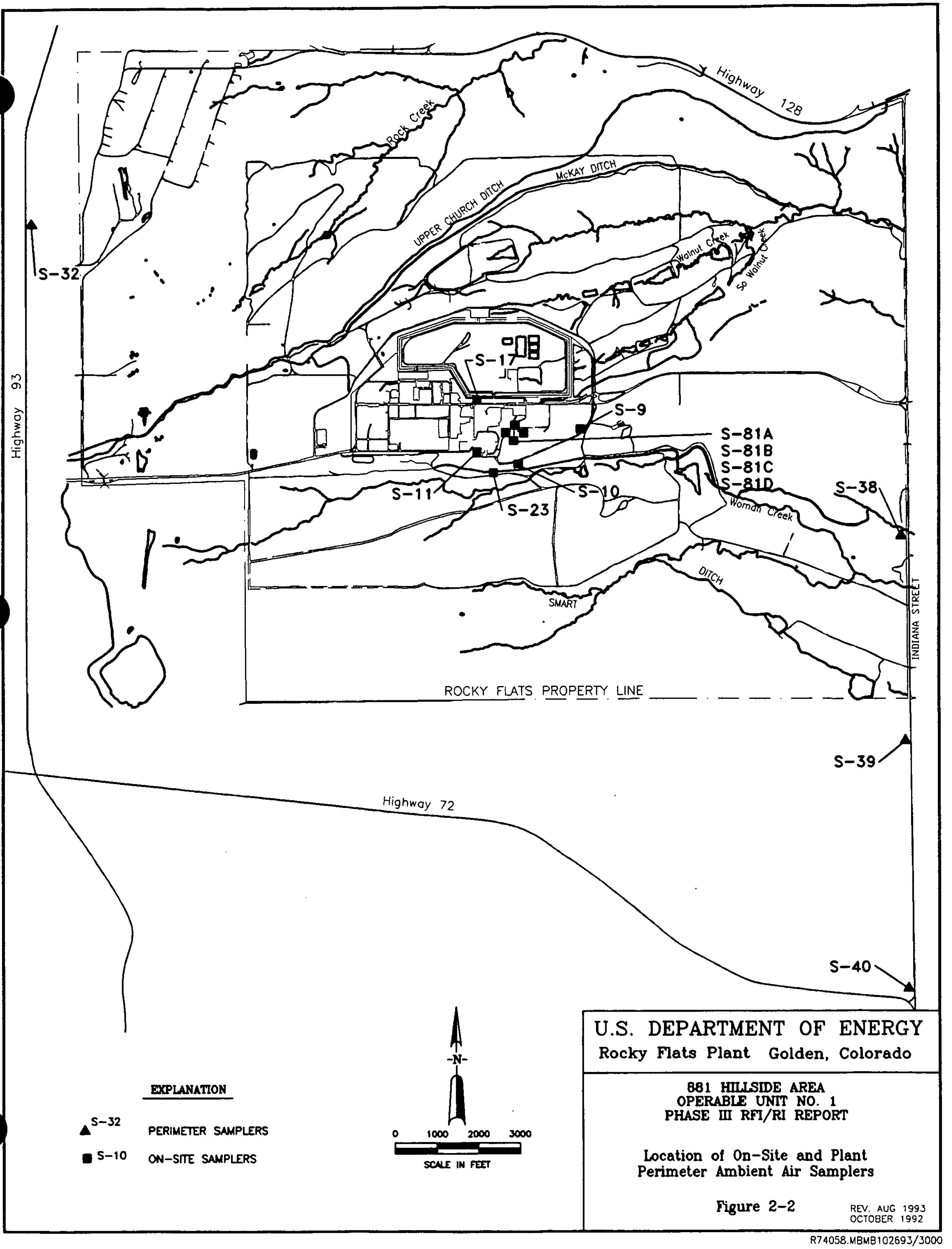
Soil Samples Collected During the Hot Spot Investigation

Sample Location	Sample Number	Depth Collected	Analyses Requested				
			Metals	Radionuclides	VOCs	SVOCs	Pesticides/ PCBs
SS100193 (IHSS 1191.)	SS10002ST	0-.25"	X	X	X	X	X
	SS10003ST	0-1.4'	X	X	NS	X	X
		1.4-1.7'	NS	NS	X	NS	NS
SS100293 (IHSS 119.1)	SS10004ST	0-.25"	X	X	X	X	X
	SS10005ST	0-2.0'	X	X	NS	X	X
		2.0-2.3'	NS	NS	X	NS	NS
	SS10006ST	2.0-3.7'	X	X	NS	X	X
		3.7-4.0'	NS	NS	X	NS	NS
SS100393 (IHSS 119.2)	SS10007ST	0-.25"	X	X	X	X	X
	SS10008ST	0-1.0'	X	X	NS	X	X
		1.0-1.3'	NS	NS	X	NS	NS
SS100493 (IHSS 119.1)	SS10009ST	0-.25"	NS	NS	X	NS	NS
	SS10010ST	2.0-2.3'	NS	NS	X	NS	NS
	SS10011ST	3.3-3.6'	NS	NS	X	NS	NS
SS100493 (IHSS 119.1)	SS10001EG*	0.75"	X	X	NA	NS	NS
	SS10002EG*	4"- 5"	X	X	NA	NS	NS
	SS10003EG*	9"- 10"	X	X	NA	NS	NS

* Original hot spot location (same location as SS100493) sampled by EG&G 14 and 15 January 1993.

NA = Not analyzed; resampled at SS100493
NS = Not sampled

Refer to Figure 4-11 for sample locations.



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Rocky Flats Plant Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

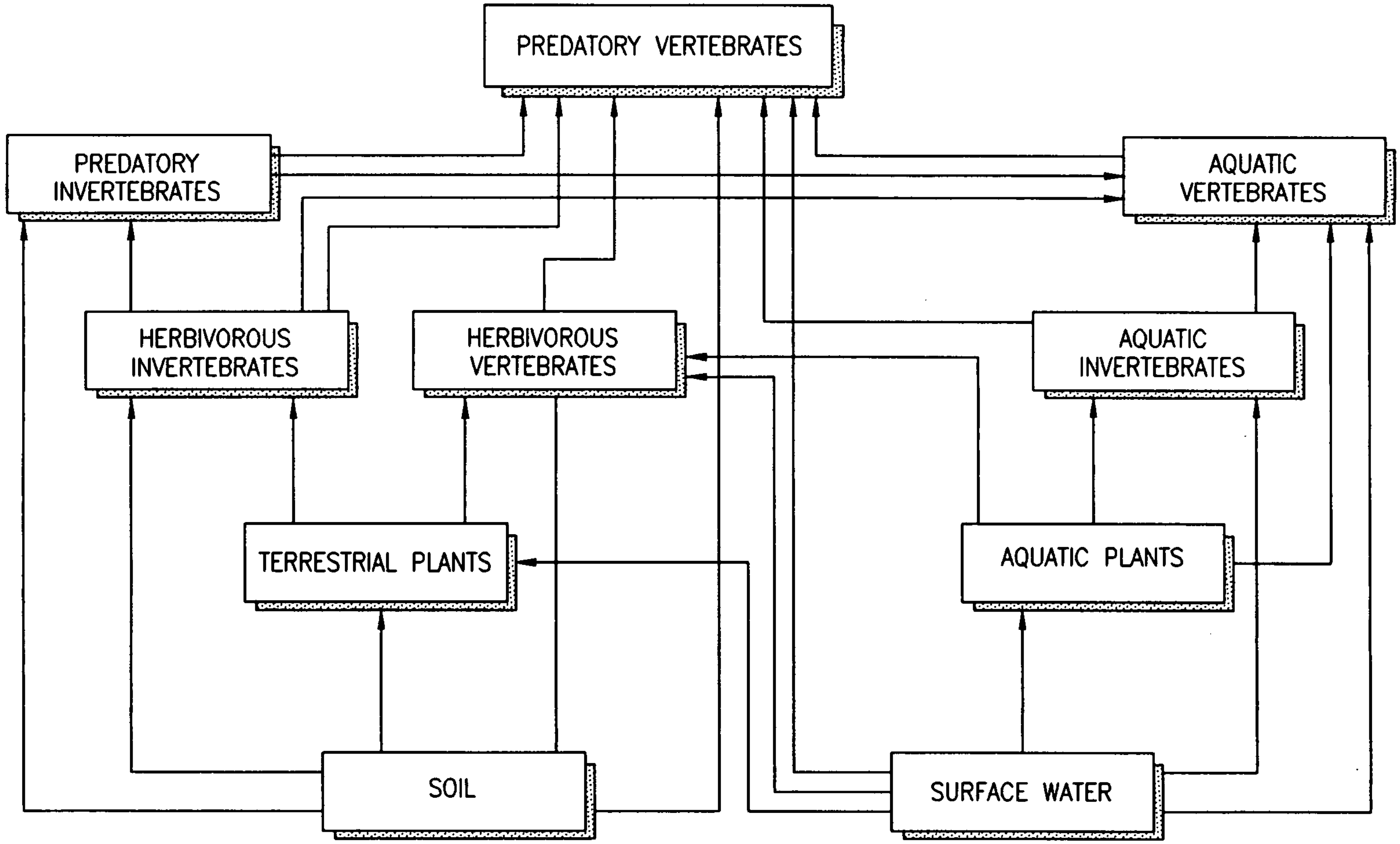
Location of On-Site and Plant Perimeter Ambient Air Samplers

Figure 2-2

REV. AUG 1993
OCTOBER 1992

R74058.MBMB102693/3000

R74265.PJ-082593



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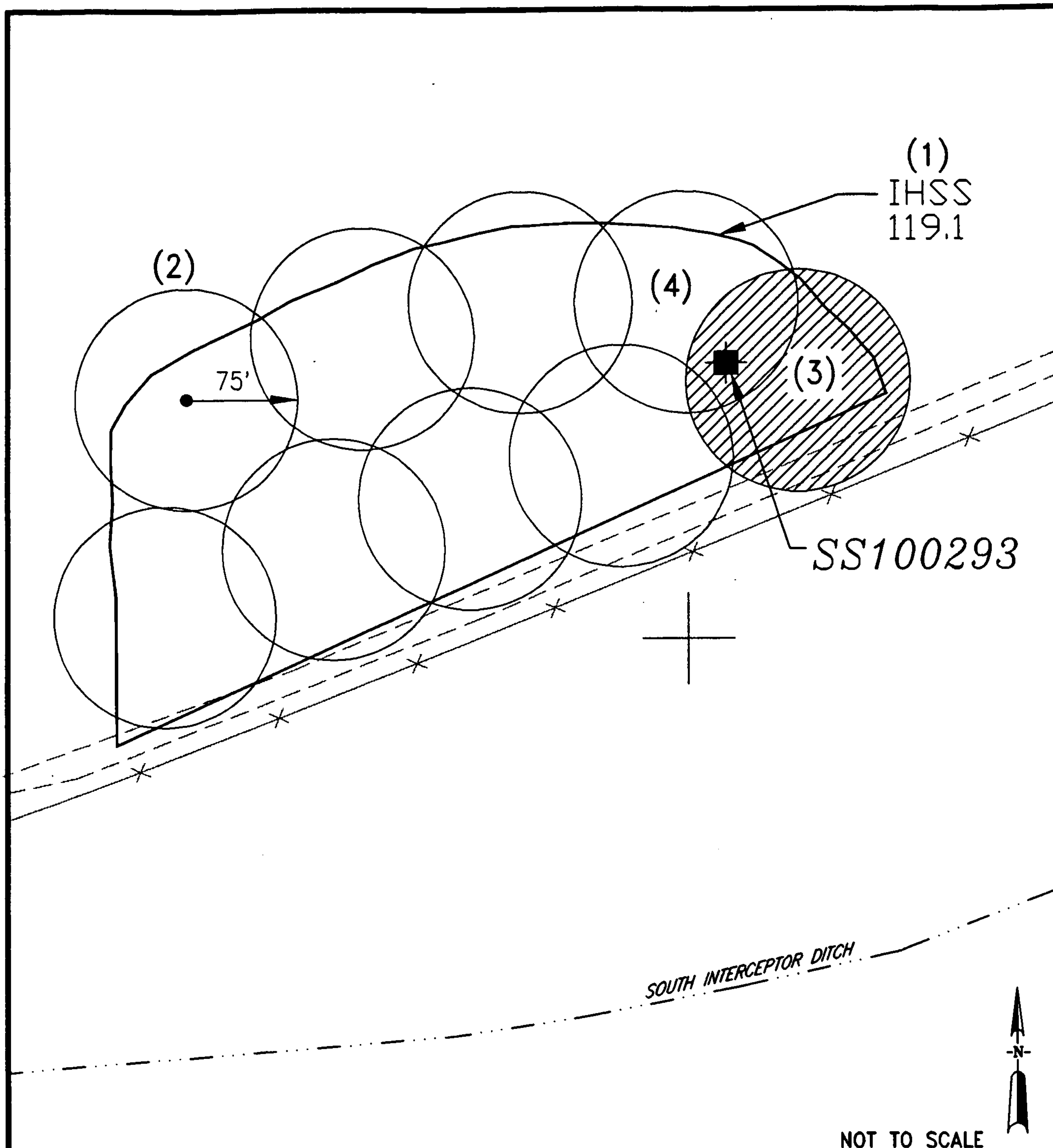
Terrestrial and Associated Aquatic Ecosystem Food Web and Exposure Pathway
Figure 2-11

REV. AUG 1993
OCTOBER 1992



EXPLANATION

104 INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS)

CHARACTERIZATION APPROACH:

1) Identify IHSS with Potential Surface Radionuclide Contamination
2) Use HPGe FGSS to get 100% Coverage of IHSS and Identify Potential "Hot Spots".
3) Conduct Walk-over Survey with FIDLER to Locate "Hot Spot".
4) Sample "Hot Spot" Locations Identified in Step 3.

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PHASE III RFI/RI REPORT

Conceptual Depiction of the OU1 Surficial Radiological Characterization Action Plan

Figure 2-15

AUGUST, 1993

R74267.PJMB102693/100

SECTION 3

PHYSICAL CHARACTERISTICS OF OU1

Section 3 describes the various physical attributes of OU1. The following sections describe surface features, demography and land use, meteorology, surface water hydrology, soils, geology, hydrogeology, and ecology. Site conditions are characterized sufficiently to determine possible pathways and assess the conditions of potential contaminant fate and transport in IHSSs at OU1.

3.1 SURFACE FEATURES

The natural environment of the plant and vicinity are influenced by its proximity to the Rocky Mountain Front Range. The plant is directly east of the north–south trending Front Range and east of the Continental Divide at an elevation of approximately 6,000 feet above mean sea level. RFP is located on a broad, eastward-sloping plain of coalescing alluvial fans developed along the Front Range (Hurr, 1976). The fans extend about 5 miles eastward from their origin at Coal Creek Canyon and terminate at a break in slope to low rolling hills near Indiana Street. The operational area at the plant is located near the eastern edge of the fans on a terrace between the stream-cut valleys of North Walnut Creek and Woman Creek.

RFP is located in northern Jefferson County approximately 16 miles northwest of Denver (Figure 1-1). Other nearby cities include Boulder, Westminster, and Arvada, which are located less than 10 miles to the northwest, east, and southeast, respectively. The plant consists of approximately 6,500 acres of federally owned land in Sections 1 through 4 and 9 through 15 of Township 2 South, Range 70 West, 6th Principal Meridian. Major buildings are located within the plant security area, which encompasses approximately 400 acres and is surrounded by a security fence. A buffer zone of approximately 6,150 acres surrounds the plant security area. Two roads allow entrance to the plant site: the West Access Road from Highway 93 and the East Access Road from Indiana Street (Figure 1-1).

OU1 is located south of the plant on a south-facing hillside that slopes down from Building 881 to Woman Creek. Topographically, the highest point near OU1 is Building 881, approximately

6,000 feet above mean sea level, and the lowest point is in Woman Creek, about 5,830 feet above mean sea level (Figure 3-1). Two gravel roads provide access to the site: one to the areas inside the perimeter fence and the other to areas in the buffer zone. Two surface drainages occur in the vicinity of OU1. Woman Creek flows along the base of 881 Hillside south of OU1, and the SID crosses OU1 between the plant and Woman Creek. A French Drain was recently constructed across a significant portion of OU1 above the SID to collect alluvial groundwater.

The terrain at OU1 varies from gently rolling to locally steep slopes on the hillside. Steeper grades are generally present near the top and bottom of the hillside with gentle, more uniform slopes in the central portion of the hillside. Natural slumping and past construction, fill placement, waste storage, and waste cleanup activities have recontoured the OU1 terrain.

3.2 DEMOGRAPHY AND LAND USE

A recent demographic study shows that approximately 2.2 million people live within 50 miles of RFP (DOE, 1990d), and approximately 9,100 people live within 5 miles of RFP (DOE, 1990d). The most populated sector is to the southeast, toward the center of Denver. Recent population estimates registered by the Denver Regional Council of Governments (DRCOG) for the eight-county Denver metropolitan area display distinct growth patterns. Between 1980 and 1985, the population of the eight-county area increased by 197,890, a 2.4% annual growth rate. Between 1985 and 1989 a population gain of 71,575 was recorded, representing a 1.0% annual increase (the national average). The 1989 population showed an increase of 2,225 (or 0.1%) from the same date in 1988 (DRCOG, 1989).

RFP is located in a rural area that is bordered by three counties. Approximately 50% of the area within 10 miles of the plant is in Jefferson County. The remainder is located in Boulder County (40%) and Adams County (10%). According to the 1973 Colorado Land Use Map, 75% of this land was unused or was used for agriculture. Since that time, portions of this land have been converted to housing, and several new housing subdivisions have been started within a few miles of the buffer zone.

There are eight public schools within 6 miles of RFP. The nearest is Witt Elementary School, which is approximately 2.7 miles east of the buffer zone. The closest hospital is Centennial Peaks Hospital, located approximately 7 miles to the northeast. The closest park and recreational area is the Standley Lake area, which is approximately 5 miles southeast of RFP. Boating, picnicking, and limited overnight camping are permitted. There are several other small community parks within 10 miles. The closest major park, Golden Gate Canyon State Park, located approximately 15 miles to the southwest, provides 8,400 acres for general camping and outdoor recreational use. Other national and state parks are located in the mountains west of RFP, but all are more than 15 miles away.

Some of the land adjacent to the plant is zoned for industrial development. Industrial facilities within 5 miles include the TOSCO laboratory (a 40-acre site located 2 miles south), the Great Western Inorganics Plant (2 miles south), the Western Aggregates, Inc. Plant (2.4 miles northwest), and the Jefferson County Airport and Industrial Park (a 990-acre site located 4.8 miles northeast). Future off-site land uses are illustrated in the North Plains Community Plan Study Area Map (Figure 3-2). Land areas closest to RFP are zoned for industrial development and those furthest from RFP are zoned for residential development.

Several ranches are located within 10 miles of the plant, primarily in Jefferson and Boulder Counties. They are operated to produce crops, raise beef cattle, supply milk, and breed and train horses.

3.2.1 Land Use at OU1

In the past, Building 881 was used for enriched uranium operations and stainless-steel manufacturing. The building is currently used for multipurpose research and development, analytical plant support, and administrative offices (CDH, 1992). The general laboratories in Building 881 perform a number of analyses on a variety of materials including wastewater, sludge, surface water, groundwater, and production control samples from Buildings 460 and 444. When the enriched uranium processes were in operation in Building 881, the laboratories also performed analyses of the materials generated in production. Other operations in Building 881 include generating chemical standards and "inertial fusion" activities, machining, gold plating, small parts assembly for weapons and energy generation research, and large machining operations.

Historically, portions of the land at OU1 have been used for disposal or storage of waste. Currently, OU1 is the site of waste cleanup activities. A U.S. Geological Survey map from 1977 (Colton and Holligan, 1977) identifies the locations of past landslides and indicates the potential for landslides in the vicinity of RFP. Therefore, future construction at OU1 would be problematic. In addition, slumping was observed and was active during excavation of the French Drain. The steepness of the slope and the potential for landslides would complicate the construction of structures on 881 Hillside.

3.3 METEOROLOGY AND CLIMATOLOGY

The RFP area has a semi-arid climate that is characteristic of much of the central Rocky Mountain region. Approximately 40% of the 15-inch annual precipitation falls during the spring season, much of it as snow. Thunderstorms (June to August) account for an additional 30% of the annual precipitation. Autumn and winter are drier seasons, accounting for 19% and 11% of the annual precipitation, respectively. Snowfall averages 85 inches per year, falling from October through May (DOE, 1980). Temperatures are moderate; extremely warm and cold weather is usually of short duration. On the average, daily summer temperatures range from 55 to 85 degrees Fahrenheit, and winter temperatures range from 20 to 45 degrees Fahrenheit. The low average relative humidity (46%) is due to the blocking effect of the Rocky Mountains.

Wind data are collected on the plant site and summarized annually. Table 3-1 presents the combined 1990 to 1991 annual summary of the percent frequency of wind directions (16 compass points) divided into five speed categories. Figure 3-3 presents these same frequency values graphically. Winds at RFP are predominantly from the northwest.

Special attention has been focused on dispersion meteorology surrounding the plant due to the possibility that atmospheric releases might affect the Denver metropolitan area, which is located in the predominant downwind direction (southeast). Studies of air flow and dispersion characteristics (Hodgin, 1983; 1984) indicate that winds come down from the mountains to the west, turn and move toward the north and northeast along the South Platte River valley, and pass to the west and north of Brighton, Colorado (DOE, 1980), which is just north of Denver.

3.4 SURFACE WATER HYDROLOGY

Three intermittent streams drain RFP and flow generally from west to east. These drainages, shown in Figure 3-4, are Rock Creek, Walnut Creek, and Woman Creek. Rock Creek drains the northwestern portion of the plant and flows northeast through the buffer zone to its off-site confluence with Coal Creek. North Walnut Creek, South Walnut Creek, and an unnamed tributary drain the northern portion of the industrial area and buffer zone. Together they flow toward Great Western Reservoir, after being intercepted by an off-site bypass ditch (Figure 3-4). An east-west trending topographic divide bisects the plant, separating the Walnut and Woman Creek drainages. Woman Creek drains the southern portion of the industrial area and buffer zone and flows eastward off site to Standley Lake (Figure 3-4). The Woman Creek drainage basin is approximately 3.1 square miles (2,000 acres) in area.

Woman Creek flows from west to east along the base of 881 Hillside south of OU1. The SID crosses 881 Hillside from west to east and lies between the industrial area and Woman Creek just above the base of the 881 Hillside slope. The SID, Pond C-1, and Pond C-2 comprise the C detention system. The SID collects runoff from the southern portion of the industrial area, including 881 Hillside, and diverts it to Pond C-2 where it is monitored in accordance with the RFP National Pollution Discharge Elimination System permit. Pond C-2 has no active outlet. Water in Pond C-2 either evaporates or is pumped to the A-series ponds in North Walnut Creek for treatment.

Surface water flows down several small gullies and drainages on the 881 Hillside and these comprise the local drainages. Water from local drainages and from overland flow is captured by the SID. In addition, the SID receives surface flows from other upstream OUs including OU5, OU10, and OU12, and one downstream OU, OU2. The SID may also interact with shallow alluvial groundwater. Because the SID is an engineered feature with a series of riprap-lined plunge pools instead of a continuous grade, it is difficult to determine from discharge gaging data whether various reaches of the ditch are gaining or losing. Seasonal contrasts in elevation between water levels and the water table differ so that recharge/discharge relationships may vary throughout the year. In the western part of OU1, the SID may gain or lose water depending on the elevation of the localized water table. In the eastern part of OU1, the SID appears to lose flow to the underlying shallow alluvial groundwater flow system because the plunge pools along this reach are almost always dry.

The relationship between rainfall and runoff depends on topography, geology, soil, and physical characteristics of an area. Peak flow and runoff volume for drainage basins at Rocky Flats and its subdivisions have been calculated using the Stormwater Management Model (SWMM). For a 6-hour storm, peak flow for 96 acres (which includes 881 Hillside and areas farther west), ranges from 6 cubic feet per second (cfs) for a 2-year event to 120 cfs for a 100-year event. Runoff volume ranges from 2-acre feet (af) for a 2-year event to 15 af for a 100-year event (EG&G, 1992d). Runoff is less for areas covered by Rocky Flats Alluvium because of higher infiltration rates (USGS, 1976). In these areas, runoff is only 1.4% of rainfall. Most runoff occurs as interflow, rather than overland flow or groundwater flow, before discharging to the SID or Woman Creek.

Although the Federal Emergency Management Agency Flood Insurance Rate maps for the area in the vicinity of RFP include a narrow strip of Woman Creek in the 100-year floodplain, (Figure 3-5), IHSSs at OU1 are above the potential 100-year floodplain. Elevations of IHSSs at OU1 range from 5,944 to 5,995 feet above mean sea level. Average stream channel elevations for Woman Creek range from 5,830 to 5,880 feet.

Twenty-one surface water stations were included as monitoring points for OU1. Most locations fall on the SID or in Woman Creek, including some points upgradient of OU1. Seeps and drains were also monitored. Flow rates at surface water monitoring stations were measured using a portable cut-throat flume. Flow measurements at 881 Hillside stations were conducted as part of the sitewide surface water monitoring program. Monitoring was performed monthly and was not scheduled around precipitation events, which accounts for the absence of flow observed at many OU1 surface water stations (Table 3-2). In addition, access to many sites was restricted during French Drain construction. However, during a site inspection in April 1993, flowing water was audible, but not visible in the rip-rapped sections of the SID. Standing water was noted in other reaches of the SID. The sitewide program was redesigned in 1992, and existing stations were replaced with alternative locations, none of which is specific to OU1. Historical surface water flow data are presented in Appendix B5.

3.4.1 881 Foundation Drain, Skimming Pond, and Seep Monitoring

Surface water stations SW044, SW045, and SW046 are just south of Building 881. Station SW044 is located on the SID and previously monitored the discharge from a pipe draining the skimming pond to the SID. The skimming pond was destroyed during construction of the French Drain.

Station SW045 monitored the foundation drain (also known as the footing drain) discharge from Building 881. Flow records from the foundation drain were maintained independently of the sitewide monitoring program. From October 1, 1991, to March 10, 1992, flow from the drain was reported to average approximately 3.4 gallons per minute (Cirillo, 1993). The foundation drain originally discharged to a sump, which then discharged at capacity to the skimming pond. The foundation drain plumbing was rerouted in March 1992, and the drain now discharges to the French Drain collection system.

Station SW046 was located just west of the skimming pond in a pond formed by groundwater seepage from the skimming pond (DOE, 1991b). Section 3.7 describes the seeps in more detail. During periods of access, there was no surface water flow in any of these monitoring stations during the 1990-1991 monitoring period (Table 3-2).

Other seeps monitored on the hillside include SW071 and SW072 at IHSS 119.1; SW125, west of IHSS 130; and SW126, south of IHSS 102.

3.4.2 SID and Woman Creek

Flow in the SID is intermittent in nature and is related to precipitation events. During periods of no measurable flow, standing pools of water occur upstream of piles of large rock riprap while the reaches of the ditch downstream from the riprap are almost always dry. Stations

SW035, SW036, and SW038 are located upgradient from OU1. Station SW031 monitors the water quality in the SID just downstream of SW044. Stations SW066, SW067, SW068, SW069, and SW070 monitor the SID downgradient from OU1. Most of the monitoring stations are located in standing pools of water. During the 1990-1991 monitoring period, station SW031 had measurable water flow only in April and May (Table 3-2). There was no surface water flow in stations SW066, SW067, SW068, SW069, and SW070 during the 1990-1991 monitoring period (Table 3-2).

Stations along Woman Creek include SW032, SW033, SW034, SW039 (upgradient), and SW029 (downgradient).

3.5 SOILS

The surface soils at OU1 are predominantly deep, well-drained loams, clay loams, and very cobbley sandy loams with moderate to slow permeability. The soils along the floodplain and low terraces of Woman Creek consist of stratified loamy alluvium from the Haverson series. The soils at the top of the hillside, where gravel and cobbles of the Rocky Flats Alluvium are common, consist of gravelly and sandy loam from the Flatirons series. Along the slope of the hill, soils consist of cobbley to sandy loamy alluvium from the Nederland series and clay loams from the Denver–Kutch–Midway series. Runoff is generally rapid, and erosion hazard can be severe on the steep portions of the hillside. Most of the soil series are classified within the Argiustoll great group (Figure 3-6 and Table 3-3). Argiustolls are generally characterized as well-drained soils with mollic (dark) epipedons, argillic "B" horizons, and calcic "C" horizons. They exist in aridic and ustic (limited moisture) regimes, which are adequate for plant growth during the growing season. The two predominant subgroups are Torrertic and Aridic. Torrertic Argiustolls have a higher shrink-swell potential than Aridic Argiustolls (Department of Agriculture, 1980).

Infiltration rates at OU1 are low compared to other areas of the plant, ranging from 2 inches per hour for initial infiltration to 0.5 inches per hour for final infiltration. This is lower than the rates calculated for the Rocky Flats Alluvium, 3.5 to 7.5 inches per hour (EG&G, 1992d).

3.6 GEOLOGY

Geologic units at RFP consist of unconsolidated surficial material and bedrock. Surficial units include Quaternary alluvial deposits, colluvial deposits, and artificial fill that are underlain by Cretaceous sedimentary rocks of the Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone. Figure 3-7 presents a generalized stratigraphic section for RFP. RFP is located just east of the Colorado Front Range in the Denver Basin, which is an asymmetrical, north–south trending syncline with a steeply dipping western limb and a shallowly dipping eastern limb (Figure 3-8). Steeply dipping Fox Hills and Laramie Formation sandstones on the western limb of the fold form a prominent hogback that strikes north–northwest. Outcrops of Fox Hills and Laramie Formation sandstones occur sporadically along the hogback. Immediately west of RFP, where the hogback is not visible at the surface, steeply dipping (45 to 55 degrees east) Fox Hills and Laramie Formation sandstones are exposed in clay pits excavated through the Quaternary gravels (Figure 3-8). Beneath RFP, the dip of Fox Hills, Laramie, and Arapahoe Formation sandstones is much shallower, at approximately 1 to 2 degrees east (EG&G, 1992b).

Geologic data used to characterize the OU1 area were compiled from previous OU1-specific studies and the present Phase III field investigation, as well as several ongoing investigations including sitewide geologic mapping, shallow seismic and drilling programs, and neighboring OU-specific studies. Data from the French Drain construction project were included where possible. All these data were integrated into the current geologic conceptual model for the OU1 site. Sections 3.6.1, 3.6.2, and 3.6.3 present descriptions of the surficial geology, bedrock geology, and geomorphology of the OU1 area. Appendix A4 provides information on the geology of the French Drain excavation.

3.6.1 Surficial Geology

Surficial material consists of Quaternary and Recent valley fill alluvial deposits, alluvial-fan deposits of the Rocky Flats Alluvium, colluvial deposits, and artificial fill. The Rocky Flats Alluvium forms the crest of the 881 Hillside area. Remnants of younger terrace deposits occur topographically below the Rocky Flats Alluvium, but have not been mapped in the vicinity of

OU1 (EG&G, 1992b). The slope of 881 Hillside is covered with colluvium and artificial fill. Valley Fill Alluvium is present along the Woman Creek drainage at the bottom of the hill.

Figure 3-9 shows the thickness and lateral distribution of these surficial materials and areas of artificial fill and disturbed soils. The Rocky Flats Alluvium is 10 to 20 feet thick and forms a blanket-like deposit on the terrace that caps the 881 Hillside area. The Valley Fill Alluvium is less than 10 feet thick and forms a sinuous elongated deposit at the bottom of the hill. Colluvium and artificial fill cover the rest of the hillside and range in thickness from 1 to 30 feet. Colluvium and fill are thickest on the hillside south and southeast of Building 881 and on the hillside just north of the perimeter fence and southeast of Building 881 (Figure 3-9). A comparison of past (1937) and present topographic contours indicates that artificial fill has been placed in these areas (EG&G, 1990e). The zones of thicker alluvium south and southeast of Building 881 correspond to possible slumps shown on the geomorphological features map (Figure 3-27, Section 3.6.3). Several of the smaller northwest-southeast trending zones of thicker alluvium correspond to paleochannels shown on the bedrock topography map (Figure 3-24, Section 3.6.2). Therefore, the thickened alluvial zones are perhaps due to a combination of alluvial channel fill deposits and artificial fill material, or to slumping.

Seven cross sections were constructed to illustrate the lateral and vertical relationships of surficial material at the 881 Hillside area. Figure 3-10 is an index map that shows where the seven cross sections are located. Figures 3-11 through 3-17 present alluvial cross-sections A-A' through G-G'. The alluvial/bedrock contact shown in the cross sections is based on well control and has been interpreted between control points using the bedrock topography map presented (Figure 3-24, Section 3.6.2).

Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and highest alluvial deposit at RFP (Scott, 1965). It is an alluvial fan deposit that occupies an extensive erosional surface beneath RFP. The alluvium ranges from 0 to 100 feet in thickness and is thickest west of RFP near the apex of the fan and thinnest just east of RFP near the depositional limit of the fan. The Rocky Flats Alluvium is composed of yellowish brown to reddish brown, angular to subrounded, poorly sorted, coarse, bouldery gravel in a sand matrix with lenses of clay, silt, and varying amounts of caliche. Pebbles, cobbles, and boulders are composed of quartzite, but include lesser amounts of schist, gneiss, granite pegmatite, sandstone, and siltstone. Gravels range from pebbles, 2 to 4 inches in diameter, to boulders as large as 2 feet in diameter (EG&G, 1992b).

After the Rocky Flats Alluvium was deposited, streams began dissecting the deposit. The alluvium was completely eroded in the Woman Creek and Walnut Creek drainages and tributaries. The Rocky Flats Alluvium that remains forms the crest of the hillside and the terrace on which RFP was built (Figure 3-9). The Rocky Flats Alluvium in well 37591 is shown in cross-section F-F' (Figure 3-16); thickness of the alluvium in this well is 12 feet. The uppermost 3 feet are composed of dark brown to reddish brown, angular to well-rounded, poorly sorted, silty sandy gravel with varying amounts of iron staining and caliche. The gravel is underlain by 9 feet of silty sand and gravelly sandy clay. The gravel and sand lenses may extend to the northwest on the pediment surface, but terminate to the southeast at the edge of the terrace and are adjacent to areas of artificial fill.

Colluvium

Colluvium covers the valley slopes between the pediment on which the Rocky Flats Alluvium is deposited and the valley bottoms. Colluvial materials have been deposited by slope wash and downward creep of Rocky Flats Alluvium and bedrock. The colluvium is heterogeneous and consists predominantly of clay with lenses of silt, sand, and gravel. Cross-sections A-A' through G-G' (Figures 3-11 through 3-17) show the occurrence of colluvial deposits across the hillside.

Colluvial clays are most abundant between the security fence and the SID, as shown in cross-sections A-A' (Figure 3-11), B-B' (Figure 3-12), D-D' (Figure 3-14), and G-G' (Figure 3-17). The clays are described as variably iron-stained, yellowish brown to very dark grayish brown, silty clay to sandy gravelly clay, with silt- to sand-sized fragments of carbonaceous material. Caliche is sometimes present. No bedding structures are apparent, and the clays generally have low plasticity. Thicknesses vary from 5 to 20 feet. The clays are derived from the weathering of bedrock, including slump blocks, and from the Rocky Flats Alluvium.

Colluvial silts are shown in cross-sections B-B', (Figure 3-12), C-C' (Figure 3-13) and E-E' (Figure 3-15). The silts are described as brown to dark yellowish brown, mottled, structureless, sandy silt with gravel. Mottling is generally due to iron staining, and caliche is sometimes present. The thickness of the silts ranges from 5 to 15 feet.

Sands in the colluvium are shown in cross-sections C-C' (Figure 3-13), D-D' (Figure 3-14), E-E' (Figure 3-15), and F-F' (Figure 3-16), and south of Building 881, as illustrated in cross-section B-B' (Figure 3-12). The sands are described as highly weathered and variably iron-stained, brown to dark yellowish brown, very fine- to coarse-grained, subangular to subrounded, well-graded (poorly sorted) silty sands with gravel and caliche cement. Individual grains are composed of quartz, feldspar, rock fragments, mafic minerals, and micas. Thicknesses vary from 1 to 5 feet.

Colluvial gravels may fill depressions in the bedrock surface southeast of Building 881, as shown in cross-sections A-A' (Figure 3-11), and also occur in lenses, as shown in cross-sections C-C' through G-G' (Figures 3-13 through 3-17). The gravels are described as light brown to dark yellowish brown, subangular to subrounded, well-graded (poorly sorted) silty sandy gravels, and sandy clayey gravels with variable amounts of caliche cement. Cobbles are composed of quartzite, granite, gneiss, and schist, and range up to 2 inches in diameter. Gravel lenses are from 2 to 6 feet thick. Although previous investigations at OU1 revealed that colluvial gravels are elongated in the north–south direction and have a rather limited extent in the east–west direction (DOE, 1991b), additional wells and boreholes added in the Phase III RFI/RI drilling program showed that colluvial gravels and sands have a limited extent in both the north–south and the east–west directions.

At OU1, colluvial deposits have been disturbed by the construction of Building 881, the SID, and the French Drain, and excavation activities associated with various IHSSs (Figure 3-9). Shallow excavation took place during the construction of roads and the leveling of the drum storage area within IHSSs 119.1 and 119.2 (Figures 3-15, 3-16, and 3-17). Colluvium was also disturbed south of Building 881 in the vicinity of IHSSs 106 and 107 during the construction of the skimming pond (IHSS, 107). Colluvium was excavated during the construction of the SID from 1979 to 1981 and during the recent construction of the French Drain.

Artificial Fill

A comparison of a 1937 topographic map (created with aerial photographs) with a recent topographic map indicates where artificial fill has been placed on 881 Hillside (EG&G, 1990e). The three primary areas delineated by this comparison are the area around Building 881, the vicinity of IHSS 130 southeast of Building 881, and a linear east-west trending zone near the top of the hill (Figure 3-9).

Material excavated from the foundation for Building 881 was spread over a large area south and west of the building. This fill material is derived from the Rocky Flats Alluvium, colluvium, and claystone bedrock, and is composed primarily of silty clay with some gravel. The fill appears very similar in composition to natural colluvium. Boreholes B302090, B304290, B302190, and B302290 encountered buried topsoil beneath artificial fill in this area (EG&G, 1990e). Thickness of the artificial fill ranges from 12 to 20 feet.

IHSS 130 was used to dispose of soil and asphalt (DOE, 1991b). Artificial fill overlies natural colluvium in this area and was encountered in boreholes 36091, 36291, and 36391. Cross-section C-C' (Figure 3-13) intersects the area with artificial fill in well 36391. The fill material is described as variably colored clays, sands, and gravels with sand-sized chunks of asphalt or tar, and is approximately 10 feet thick. Artificial fill is also described in core logs from boreholes 36091 and 36291 (cross-section D-D', Figure 3-14). In borehole 36091, the fill is 5 feet thick and characterized as silty, sandy gravel with asphalt-cemented chunks up to 2 inches in diameter. In borehole 36391, the fill is 4 feet thick and described as very dark gray, well-graded sand and gravel in a clay matrix with sand- and gravel-sized pieces of asphalt throughout.

Artificial fill was also placed in a linear east-west trending zone near the top of the hill, east of Building 881 and south of the 904 Pad, to extend the contractor trailer yard (EG&G, 1990e). This material is very similar to natural colluvium and alluvium and has not been distinguished in drill cores. Cross-section F-F' (Figure 3-16) shows an area near the top of the hill where fill may have been placed.

Valley Fill Alluvium

Valley Fill Alluvium makes up the channel and terrace deposits in and along Woman Creek. The alluvium is 4 to 8 feet thick and is derived from reworked and redeposited alluvium and bedrock. Lithologically, the Valley Fill Alluvium is composed of organic-rich, dark brown to very dark grayish brown, subangular to subrounded, poorly sorted coarse gravel in a clayey sand matrix. Pebbles and cobbles are composed of quartzite, schist, gneiss, granite, and some ironstone. Gravels range from pebbles 1 to 4 inches in diameter (noted in the drill core) to boulders (observed in the field). The matrix consists of medium-grained quartz, feldspar, and biotite sand grains with varying amounts of clay. Valley Fill Alluvium is present in wells 5886, 6886, 38591, 5587, 30991, 39891, and 6486, and in boreholes 32291, 38391, 38491, 38691, 38791, and 30091.

3.6.2 Bedrock Geology

At OU1, alluvial material is unconformably underlain by Cretaceous sedimentary rocks of the Laramie Formation. This geologic interpretation differs from the one presented in the recently completed surface geologic mapping report (EG&G, 1992b) and the Phase II RI Report (Rockwell, 1988a) in that no Arapahoe Formation is shown. The reinterpretation of bedrock geology at OU1 is explained below.

In general, the base of the Arapahoe Formation is marked by the presence of medium-grained to conglomeratic sandstones composed of well-rounded, frosted quartz sand grains with pebbles of chert, rock fragments, and ironstone (EG&G, 1992b). Sandstones exhibiting these distinctive characteristics are not exposed at the surface nor in any of the drill cores from OU1. Because most of the bedrock at OU1 is stratigraphically lower than bedrock interpreted as the basal Arapahoe Formation, and because no sandstones exhibiting the discriminating characteristics (noted above) of the marker bed at the base of the Arapahoe Formation are found at OU1, all bedrock underlying OU1 is considered to be part of the upper Laramie Formation.

Laramie Formation

The Laramie Formation is informally subdivided into two members: an upper claystone member and a lower sandstone member. The upper claystone member is 300 to 500 feet thick. It is composed primarily of light to medium gray, structureless claystones with some dark gray to black carbonaceous claystones and thin coal beds and a few thin discontinuous silty sandstone beds. The discontinuous sandstones of the upper claystone member are light gray to olive gray, very fine- to medium-grained, subangular to subrounded, moderately to well sorted, and quartzose in composition with a few coal fragments. Small ironstone nodules and calcite blebs occur infrequently. Sedimentary structures are evident in some of the clayey siltstones and silty sandstones and include planar and climbing ripple laminations and convoluted bedding indicative of soft sediment deformation. Fractures are common and are oriented at near horizontal and near vertical, lending the bedrock a blocky texture. Most fractures are healed and exhibit iron staining along fracture surfaces.

In direct contrast to the overlying basal Arapahoe Formation sandstones, few rounded, frosted quartz grains and few rock fragments are present in upper Laramie Formation sandstones. The petrographic distinctions between Laramie and Arapahoe Formation sandstones are readily recognized with a hand lens (EG&G, 1992b). The upper Laramie Formation sandstones are also typically more fine grained than the Arapahoe Formation sandstones. The lower sandstone member of the Laramie Formation is approximately 300 feet thick and is composed of light gray, fine- to coarse-grained, subangular to subrounded, moderately to well-sorted quartzose sandstone with numerous claystone and sub-bituminous coal beds (EG&G, 1992b).

Three cross sections were constructed to illustrate the lateral and vertical relationships of the claystones, siltstones, and silty sandstones in the upper Laramie Formation bedrock. Figure 3-18 is an index map that shows the locations of the three cross sections, and Figures 3-19 through 3-21 are the respective bedrock cross sections (H-H', I-I', and J-J'). Figure 3-22 shows the areal distribution of subcropping sandstone beds, which occur directly below unconsolidated material. The overburden/bedrock contact shown in the cross sections is based on well control and has been interpreted in between control points using the bedrock topography map (Figure 3-23).

Cross-section H-H' (Figure 3-19) shows the nature of the bedrock beneath IHSS 119.1 in a west–east direction. A fairly continuous sandstone/siltstone bed is present 35 to 40 feet below the ground surface. The sandstone/siltstone bed is approximately 10 feet thick and is sandwiched in between massive, impermeable claystones. Lithologically, this unit is described as a yellowish gray to yellowish brown, friable iron-stained, clayey siltstone to very fine-grained, clayey sandstone. Wells 37991, 0587, and 37891 are screened in this sandstone/siltstone unit.

Cross-section I-I' (Figure 3-20) illustrates the extent of the same sandstone/siltstone bed from IHSS 119.1 southeast to the French Drain. Wells 37891 and 39191 are screened in this unit, which thins to the southeast to only 2 or 3 feet in the French Drain excavation. Well 39291 and piezometer 38991 are screened in a siltstone bed 5 to 10 feet beneath the above-mentioned sandstone/siltstone bed. These siltstones are separated by 5 to 10 feet of claystones.

Cross-section J-J' (Figure 3-21) shows the nature of the bedrock from IHSS 119.2 down the hillside to the southeast. Well 4587 in IHSS 119.2 is screened in a sandstone 96 feet below the ground surface. Lithologically, the sandstone is described as a light gray to light brown, iron-stained, very fine- to medium-grained quartz sandstone. This sandstone may correlate with a similar fine- to medium-grained sandstone at a depth of 55 feet in well 6286.

Although claystones are predominant, siltstones and fine-grained silty sandstones subcrop beneath the unconsolidated material in wells 36591, 32691, 31291, B302090, B301190, 31491, 31891, 39691, boreholes B300190, B300290, and B300890, and in the French Drain excavation. Figure 3-22 shows the areal distribution of subcropping sandstones and siltstones in the upper Laramie Formation based on drill-core descriptions. Most of the subcropping fine-grained sandstones and siltstones are isolated occurrences, so the geometry of the sand bodies and their lateral extent is unknown. A few of the subcropping sandstones and siltstones exhibit a shoestring-like geometry. As seen in Figure 3-22, the subcropping sandstones and siltstones are located in IHSS 119.2, downgradient of IHSS 119.2, downgradient of IHSS 119.1 along the French Drain, and in the vicinity of Building 881. The remainder of the 881 Hillside area is underlain by more impermeable bedrock claystones.

Excavation during construction of Building 881 and installation of the foundation drain pipe has obviously altered the bedrock topography in the northwestern portion of OU1. In the remainder of the hillside, however, the bedrock topography map (Figure 3-23) portrays a relict claystone surface scoured and shaped by various alluvial, fluvial, and geomorphological processes. The features most apparent are several northwest-southeast trending paleochannels (and potentially active channels) separated by bedrock highs. Locally, the surface expression of these channels appears as small swales as seen in the drainages near well 0487 and destroyed well 0687. These features can be compared on a larger scale in Figures 3-24 and 3-25, which show the bedrock topography and surface topography, respectively, in the area and 119.1. The drainages are apparent on a 1969 aerial photograph of 119.1, which also clearly illustrates the locations of drum storage (Figure 3-26).

The bedrock topography map (Figure 3-23) was drawn using bedrock depths reported in the geologic borehole logs. The French Drain excavation investigation showed that, in some cases, slump blocks have obscured the original bedrock surface and that some bedrock identification made during drilling at OU1 were actually transported bedrock. Despite this problem of identification, Figure 3-23 clearly shows that unconsolidated material rests on an uneven surface. Typically, relatively thicker alluvial/colluvial sections are associated with bedrock lows (Figure 3-9). Slumping and its significance are discussed further in the next section.

3.6.3 Geomorphology

The geomorphology of a site can influence potential contaminant transport pathways, including surface water and groundwater flow. The geomorphology at OU1 reflects the interaction of several erosional and depositional processes on the bedrock and surficial materials underlying the site and accounts for the gently rolling to moderately steep slopes developed on 881 Hillside. Subsequent to the initial siting of the plant, the terrain has been recontoured in several areas at various times. These include the construction of Building 881, the placement of fill and waste materials in several areas including the contractor yard and several IHSSs, the grading of roads at the site, the construction of the SID and, most recently, the construction of the French Drain. Although these man-made features and activities have obscured or modified the surface expression of many of the natural geomorphological features, the preexisting site geomorphology was interpreted during the Phase III RFI/RI using historical aerial photographs to better delineate potential groundwater flow pathways.

The steepness of the hillside, combined with various construction and excavation activities at OU1, has resulted in mechanical failure manifested in widespread slumping of material. Features observed with the slump blocks, such as slickensides, are not consistent with slumps caused by soft sediment deformation. Slumps may be derived from unconsolidated material, from bedrock that has spalled, and probably most commonly, a combination of both. The number of damaged wells on the hillside testifies to the prevalence of earth movement. The slumping phenomenon is well illustrated in the panels prepared during excavation of the French Drain (Appendix A4), where slump blocks were distinguished by bounding glide planes and, less commonly, seeps and slickensides.

Recent observations of the excavated trench during the construction of the French Drain confirmed the existence of slumps on the 881 Hillside. Slumps occur in overburden and bedrock material. Those shallow slump-related features that were encountered included low angle fractures, shear planes, and overburden materials overridden by bedrock slumps (Appendix A4). A panel from the French Drain geotechnical investigation illustrates a slump block bounded by a large, west-dipping glide plane (Figure 3-27). Caliche was observed to cement various portions of the fractures and glide planes, indicating that groundwater containing carbonate had been transmitted along the fracture surfaces at one time. Excavation for the French Drain caused reactivation of some of those features on the uphill side of the open trench.

Previous studies have also delineated slumps in the 881 Hillside area. In a regional study the U.S. Geological Survey published a photograph-interpretive map of the Louisville quadrangle showing areas of landslides and areas susceptible to landslides (Colton and Holligan, 1977). The Colton and Holligan map shows the entire hillside as being susceptible to landslides.

Several seeps were inferred to be present on the hillside (Figure 3-28), most of which were observed along the rim of the hillside. These seep locations are associated with the contact of the Rocky Flats Alluvium and the bedrock at the top of the hill. Additional seeps were observed near the uppermost extent of the areas of slumping, and a few were observed to be present along the margins of slumps. The identified seeps were inferred on the basis of patches of darker-toned soils and vegetation present in summer-season photographs. Such visual characteristics are considered to be indicative of surface discharge of groundwater or the presence of very shallow groundwater, which supports a more lush vegetation. In general, the inferred seeps are confined to small depressions.

3.6.4 Faults

During construction of the French Drain, a structure was encountered in the bedrock at station 11 + 80 that was planar and flanked by silty claystone on one side and sandy clayey siltstone on the other. Caliche was present along with the contact between these units. Only a 2- to 3-foot vertical section of the structure was exposed at the based of the trench.

The structure exhibited a north–south strike with a dip of 45 degrees east. Neither gouge nor breccia was visible on either side of the structure. The shear plane was not visible due to the high degree of caliche cementation. The upper portion of the structure appeared to be truncated by an erosional surface overlain by gravelly clay.

The origin of the structure may be interpreted as a normal fault or a back thrust associated with thrust faulting. There is currently no compelling evidence to accept either interpretation. For example, the siltstone strata, located in the hanging wall east of the structure, had a bedding dip of 10 to 20 degrees to the west with a north–south strike. As the siltstone strata approached the fault plane from the east, the bedding angle changed to a dip of 10 degrees to the east. This indicated drag in the hanging wall resulting from movement along the fault. This drag folding is characteristic of a normal fault, with the east hanging wall moving down relative to the west foot wall (Billings, 1972) in an extensional regime. Claystone west of the fault was massive and did not exhibit apparent bedding in the exposed excavation. A sequence of sandy clayey siltstone and silty sandstone overlying silty claystone was observed at station 11 + 30 west of the fault. This siltstone and sandstone sequence was similar to the stratigraphic sequence immediately east of the feature at station 11 + 85, supporting the interpretation that the down-thrown block is the hanging wall of a normal fault. Conversely, a previous report (EG&G, 1992b) suggested the structure is the result of a compressional regime, which supports a possible back thrust origin. A thorough investigation of the structural regimes is needed to determine the origin of the structure, which is beyond the scope of work of this project.

3.7 HYDROGEOLOGY

As defined in the *Final Groundwater Assessment Plan for Rocky Flats* (DOE, 1992a), the uppermost aquifer at RFP is unconfined and is composed of Rocky Flats Alluvium, Valley Fill Alluvium, colluvium, bedrock sandstones, and weathered claystones of the Arapahoe and Laramie Formations. In general, evaluation of the Phase III RFI/RI and previous investigation results for OU1 indicate that two hydrostratigraphic units (HSUs) are present, an upper HSU (UHSU) and a lower HSU (LHSU), although defining the boundary is difficult. The two HSUs at OU1 exhibit different hydrogeological characteristics (markedly different potentiometric heads, and recharge/discharge mechanisms). The UHSU comprises the saturated portion of Quaternary and Recent unconsolidated surficial material, weathered claystones, including slump blocks, and a few discontinuous subcropping sandstone bodies. The UHSU is likened to the previously define uppermost aquifer.

The upper portion of the bedrock (upper 25 feet) is included in the UHSU as it was observed (during French Drain construction) to contain saturated fractures and slump block glide planes which extend upwards to the bedrock/colluvial contact, suggesting hydraulic communication between the upper bedrock and colluvium. No slump block glide planes or saturated fractures were noted below 25 feet below the colluvial/bedrock contact. All UHSU groundwater occurs under unconfined conditions.

The LHSU comprises the water bearing formations below the UHSU and is composed chiefly of Cretaceous claystones and discontinuous beds of siltstone and sandstone. Lithologically, there is no distinction between the upper portion of the LHSU and the lower portion of the UHSU in that both are characterized by fractured claystone and have similar hydraulic conductivities. However, based on the geology observed during French Drain construction and in cores retrieved during drilling, LHSU claystones become increasingly more massive (less fractured) with depth and contain little or no water. While the claystones of the LHSU are generally unweathered, some weathered claystones are present at depths of 50 feet or more as evidenced of iron staining on fracture surfaces.

Sandy and silty layers within the LHSU are water bearing and can be confined or unconfined. The most obvious distinction between the UHSU and LHSU is the differing potentiometric heads. Unconfined UHSU groundwater typically occur within 15 feet of the ground surface while water levels in LHSU wells (confined or unconfined) occur at depths that vary from approximately 30 feet to 90 feet below the ground surface, depending on where the wells are screened.

Data from three investigative programs conducted at OU1 were evaluated to characterize hydrogeological conditions at the site. Although this section focuses primarily on the Phase III RFI/RI data, additional evaluation of the Phase I and II RI and French Drain geotechnical investigation data are included. Data from these programs include geologic borehole logs; water level data from wells and piezometers; and results of geotechnical analyses, borehole and well hydraulic conductivity tests, and multiple-well pumping and tracer tests for surficial and bedrock materials. Geomorphological data and vegetation distribution data were also evaluated to better define hydrogeological conditions at OU1. Figure 3-29 shows borehole, well, and piezometer locations for all three investigative programs.

Section 3.7.1 evaluates the hydrogeological data collected for the UHSU. Characteristics of different materials are discussed in relation to the transmission of groundwater. In addition, groundwater level maps for dry and wet seasons are presented along with discussions of groundwater pathways. Section 3.7.2 evaluates data for the LHSU. Section 3.7.3 presents an evaluation of hydrogeological conditions at OU1 during the Phase III RFI/RI and subsequent to the installation of the French Drain. Section 3.7.4 is a summary of hydrogeological conclusions.

3.7.1 UHSU Data

The UHSU at OU1 is defined as unconsolidated sediments and upper bedrock containing groundwater under unconfined conditions. The UHSU is generally composed of Rocky Flats Alluvium, Valley Fill Alluvium, colluvium and disturbed colluvium, and artificial fill material.

In addition, the upper 25 feet of weathered claystones and sandstones are designated as UHSU because of the potential for unconfined groundwater transport between unconsolidated sediments and bedrock fractures, including glide planes bounding slump blocks. Based on the French Drain investigation, weathered claystones with water-bearing open fractures were observed below the overburden contact. Likewise, the proximity of subcropping sandstones to surficial material makes it possible for UHSU groundwater to flow in these relatively coarse-grained rocks. Therefore, these discontinuous beds are also categorized as UHSU.

As shown on the surficial geology and overburden thickness map (Figure 3-9), the thickness of the surficial material ranges from approximately 1 foot to 30 feet. In general, an approximate correlation occurs between thick zones and the location of paleochannels. Only a thin veneer of overburden mantles the bedrock ridges. Thick zones also occur in the western portion of OU1 where artificial fill has been dispersed during the construction of Building 881, numerous storage locations, and roads. The thinnest zones occur in the central and eastern portion of OU1 where native materials cover the relatively shallow bedrock. Along the rim of the hillside, the UHSU is composed of Rocky Flats Alluvium. Along Woman Creek, south of OU1, the UHSU is composed of Valley Fill Alluvium.

3.7.1.1 Summary of Geotechnical Data and Aquifer Test Data

Geotechnical analyses were performed on 40 samples of UHSU materials collected from 15 boreholes drilled during the Phase III RFI/RI. Table 3-4 presents the results for these samples, which include four results from weathered bedrock of the UHSU. In addition, geotechnical analyses were performed on 12 samples collected from UHSU bedrock materials during the French Drain geotechnical investigation (EG&G, 1990e); Table 3-5 presents results of these analyses. Back-pressure permeabilities, which can be used as an estimate of vertical hydraulic conductivities, ranged from 1.2×10^{-3} to 2.5×10^{-9} centimeters per second (cm/sec) for UHSU unconsolidated materials (Table 3-4). Back-pressure permeabilities from French Drain geotechnical investigation samples ranged from 1.5×10^{-6} to 6×10^{-9} cm/sec for UHSU bedrock materials (EG&G, 1990e). Thus, more variability is observed in unconsolidated material than in bedrock. This wide range of values is expected because geological characteristics that control permeabilities vary widely in the materials that comprise the unconsolidated material of the UHSU. In samples of unconsolidated material collected at depths down to 14 feet, grain sizes and lithologies range from sand to clay with varying amounts of gravel, moisture content ranges from 8 to 26%, and densities vary by 15%.

Table 3-6 summarizes hydraulic conductivity estimates from 12 single-well tests conducted during the Phase I and II RI. The wells are screened in colluvium, Woman Creek Valley Fill Alluvium, sandstone, and weathered claystone. The overall range of hydraulic conductivity values estimated for UHSU materials was 3 x 10^{-3} to 2 x 10^{-6} cm/sec. The lower values of this range are associated with weathered claystone, and the higher values with Woman Creek valley fill alluvial materials. It is interesting to note that a drawdown recovery test at a depth of 19 to 28 feet in a sandstone at well 5986 indicated a hydraulic conductivity of 3 x 10^{-4} cm/sec, within the range of values for unconsolidated materials.

Table 3-7 summarizes hydraulic conductivity estimates from 15 single-well tests conducted during the Phase III RFI/RI. The wells are screened in Rocky Flats Alluvium, colluvium, disturbed colluvium, Valley Fill Alluvium, and sandstones and claystones of the UHSU. The overall range of hydraulic conductivity values estimated for UHSU materials was 4 x 10^{-4} to 9 x 10^{-7} cm/sec using the Bouwer and Rice (1976) method of analysis. This range is wider and includes lower values than those measured during previous investigations. The difference in ranges can be attributed to the relatively low values determined for two wells (35691 and 36191) screened in disturbed colluvium. Results from the Phase I and II RI well tests do not include values for disturbed colluvium, which appears to have lower values than those calculated for claystone. The hydraulic conductivity of the subcropping sandstone at well 31891 is similar to the value calculated for a gravelly silty sand designated as Woman Creek Valley Fill Alluvium. This demonstrates the significance of coarse-grained material, cemented or not, to groundwater flow. Appendix B1 summarizes the methods of data collection and data analyses and presents a compilation of the results for the Phase III RFI/RI.

During the French Drain geotechnical investigation, 67 packer injection tests were performed in bedrock material at 21 boreholes; Table 3-8 presents results of these tests. All tests were conducted in weathered bedrock units. Resulting hydraulic conductivities ranged from 2.3 x 10^{-3} to 3.6 x 10^{-7} cm/sec (EG&G, 1990e). Table 3-5 presents back-pressure permeability and horizontal hydraulic conductivity values determined from packer tests during the French Drain geotechnical investigation. Horizontal hydraulic conductivities are 10 to 1,000 times greater than vertical permeabilities for all bedrock materials tested. This relationship is expected because the bedrock is composed predominantly of claystone. Clay particles are flat or platy in shape and are preferentially deposited with their long axes oriented horizontally. This configuration reduces vertical permeability.

During the Phase III RFI/RI, multiple-well pumping and tracer tests were conducted in Woman Creek Valley Fill Alluvium of the UHSU. The test site was located in OU5 where the saturated alluvium was thick enough to conduct the test. The multiple-well pumping test was conducted to characterize transmissivity and specific yield of the Woman Creek Valley Fill Alluvium. The tracer test was conducted to estimate contaminant transport characteristics such as effective porosity, linear dispersivity, and average linear velocity. Appendix B2 presents the rationale, data collection, data analysis, and results of these tests. For the multiple well pumping test, transmissivity was estimated at 0.2 foot^2/min (3.1 cm^2/sec), and hydraulic conductivity was estimated at 2.9×10^{-2} cm/sec based on the Theis recovery method of analysis. For the tracer test, average linear groundwater velocity was estimated at 0.07 ± 0.02 feet/min ($3.6 \times 10^{-2} \pm 0.01$ cm/sec), longitudinal dispersion was estimated at 0.2 ± 0.1 feet^2/min (3.1 ± 0.62 cm^2/sec), and effective porosity was estimated to be 5 to 10%. The measured value for flow velocity is based on flow induced by pumping.

In summary, the hydrologic data show that a wide range of hydraulic conductivity values characterize the surficial materials at OU1. Subcropping sandstones and alluvial sediments have higher hydraulic conductivities than disturbed colluvial sediments and weathered claystone. Also, the horizontal hydraulic conductivity values in bedrock appear to be 10 to 1,000 times greater than values in the vertical direction.

3.7.1.2 Discussion of Groundwater Level Data

Twenty-three monitoring wells screened in the UHSU existed prior to the Phase III RFI/RI. Water levels in these wells rise annually in response to spring recharge (second quarter) and decline during the remainder of the year. Appendix B3 presents tables and hydrographs that show the fluctuations of water levels in OU1 wells for the period from September 1986 to June 1992. Seasonal water level fluctuations range from approximately 6 to 10 feet in monitoring wells 4887, 0687, 0487, 6486, and 6986. Monitoring wells 5886, 4487, 5087, and 5187 are consistently dry or have only residual water in the sump below the well screen. Wells 5587, 4987, and 4787 are usually dry but occasionally exhibit water levels above the base of the screened interval during months of high precipitation. Four monitoring wells (5986, 6986, 0287, and 0687) screened in the surficial materials were damaged during the construction of the French Drain in late 1991 and were abandoned. Wells 0974 and 1074 were abandoned in May 1992 after completion of the Phase III investigation. Well and borehole locations are shown in Figure 3-29.

During January 1992, water levels were measured in existing wells and in 23 new monitoring wells and 4 new piezometers installed in UHSU materials during the Phase III RFI/RI (Table 3-9). Figure 3-30 is a water table elevation map for this period, which represents low water level conditions. The water table elevation map was constructed using water level measurements, recharge/discharge characteristics of the UHSU, flow control parameters (e.g., the depth to and configuration of the bedrock surface), geomorphological features such as seeps and slumps, and the historical topography map (e.g., excavation and artificial fill). Wells 31891 and 39691 are included on Figure 3-30 as they were completed in a subcropping sandstone. Well 31491 is screened over a clay and sandstone interval.

Well 6286 represents a completion in UHSU bedrock. However, water levels in this well are typically 10 feet below those of nearby UHSU well 6386, indicating some isolation between the completion zones. For this reason, data from this well are shown but not contoured on UHSU maps. The water quality samples collected at this well may also reflect local conditions in the UHSU rather than the LHSU. This issue is discussed in Section 4. Similarly, piezometer 38991 was completed in the claystone of the UHSU. Water levels for this monitoring point are shown but not contoured.

On Figure 3-30, a well is listed as dry if there was no measurable water, if the water was below the bottom of the screen, or if the well was not accessible and had historically been dry during January. This presents a dilemma for Phase III wells that were not sampled in January because of access difficulties, as historical data do not exist. In these few instances, data from January 1993 were used to determine whether a well that was not monitored should be designated as dry in January. Also, in areas of minimal well coverage, historical data from destroyed wells were used to extrapolate groundwater levels. Areas where little control exists are represented by dashed lines.

The water table elevation map clearly illustrates that the UHSU is not uniformly saturated across OU1. In the central part of OU1, dry areas alternate with areas that are saturated. A review of Figures 3-9 and 3-23 reveals that wells with measurable groundwater levels are generally located in paleochannels where thicker sections of colluvial/alluvial materials have accumulated, while dry areas appear coincident with bedrock ridges and areas with thin sections of surficial material. Where well control is minimal, the bedrock topography map and the surficial thickness map were used to extrapolate where saturated and dry areas might extend. The groundwater contour map illustrates that during January 1992 (a dry season) it is probable that groundwater pathways existed from OU1 to Woman Creek.

The area north of IHSSs 104, 119.1, and 119.2 is inferred as possibly containing groundwater based on boring information. Most of the borings drilled in this area in June 1987 indicated damp or moist colluvial/alluvial material. It is also reasonable to assume that some avenues must exist for groundwater to migrate to the hillside from the area to the north of OU1. However, much of the area in question contains thin sections of surficial materials, leaving it speculative as to how much groundwater actually exists.

Average horizontal groundwater gradients, based on the slope of the water table along potential groundwater flow paths in the western portion of the site, range from 0.11 to 0.13 feet/foot in the colluvial materials of the UHSU. A gradient of approximately 0.15 feet/foot exists in the vicinity of IHSS 119.1. The average gradient for Woman Creek Valley Fill Alluvium is 0.025 feet/foot.

Figure 3-31 illustrates the relationship between the thickness of saturated overburden in the UHSU and the distribution of groundwater during first quarter 1992. Examination of this figure with Figures 3-9 and 3-23 shows that the wells with the thickest saturated sections (5287, 35691, 0487, 38191, and 37191) are located in paleochannels with overburden thicknesses ranging from 14 to 25 feet. Other factors that tend to enhance the saturation of a localized area are the presence of coarser-grained lithologies and proximity to Woman Creek and SID areas of recharge.

The western part of OU1 contains relatively large uninterrupted areas of saturated section. The source of groundwater in this area is most likely seepage from the Rocky Flats Alluvium along the rim of the hillside, historical discharge from the Building 881 foundation drain system, and discharge from the SID that runs through the area. The UHSU is thinner in the eastern portion of the site where the bedrock surface is high. Recharge in this area is attributed to subsurface seepage from the Rocky Flats Alluvium, and the losing reaches of the SID and Woman Creek.

Table 3-10 presents additional water level data collected from first and second quarter 1992. Since water levels are typically at their maximum in April, an April water table map was constructed to represent high water table conditions at 881 Hillside (Figure 3-32). Five of the wells recorded as being dry in January had measurable water levels above the base of the screen in April, illustrating the importance of seasonal recharge to the UHSU. A higher water table is evident in the eastern portion of the 881 Hillside area where increased precipitation and snowmelt are primarily responsible for an increase in thickness and extent of the saturated surficial material in this area. Selected areas that were previously dry show some saturation in April, and some dry areas that remained decreased in areal extent. In contrast, in the western portion of the 881 Hillside area, south of Building 881, water levels appear to have decreased north of the newly installed French Drain. As discussed in detail in Appendix B4, this lowering of the water table is caused by the diversion of the Building 881 foundation drain discharge to the French Drain in February 1992. Figure 3-33 is an enlarged view of water levels in the vicinity of IHSS 119.1, and shows how the water table surface closely follows the bedrock surface.

Based on these findings, it is expected that as water levels decline during subsequent dry seasons (expected to occur in third, fourth, and first quarters due to lower precipitation and higher evapotranspiration), the UHSU south of Building 881 will exhibit lower water levels than observed to date.

Water levels from first quarter 1992 were plotted on cross sections that correspond to lithologic cross sections in Section 3.6.2. These hydrogeologic cross sections show the elevation of the water table in UHSU materials relative to topographic and bedrock surfaces (Figure 3-34). Figures 3-35 (cross-section A-A') and 3-36 (cross-section B-B') are east–west and north–south cross sections in the western portion of OU1. Cross-section A-A' shows the channel-like configuration of the bedrock surface roughly perpendicular to groundwater flow. Cross-section B-B' presents the configuration of the water table along the groundwater flow direction in this area. From these figures it appears that groundwater should be intercepted by the French Drain under current conditions. At lower elevations, between the SID and the former Retention Pond, the bedrock surface is relatively high and the colluvium is thin. As water levels rise in this area, the colluvial water table may intersect the ground surface, and groundwater may discharge at the ground surface and flow downgradient toward Woman Creek.

Figure 3-37 (cross-section C-C') is an east–west cross section of the area west of IHSS 119.1. The relatively high water level in well 37191 is most likely due to the presence of a seep in this area (confirmed by cattails and moist soils southeast of well 37191). Well 36691, which is dry in January, is screened in a caliche-rich zone that may extend between wells 36691 and 37191 and function to restrict groundwater flow. Thin overburden cover, lithology, and screened interval can also affect the response in a well, as seen in well 33891, which monitors a 2-foot-thick section of clay and claystone and is dry in January and April 1992 (Figures 3-14 and 3-38).

Figure 3-39 (cross-section E-E') is southwest–northeast trending cross section that encompasses IHSSs 119.1 and 119.2. This cross section illustrates the localized paleochannels in the bedrock surface that direct the groundwater within the UHSU. Cross-sections F-F' (Figure 3-40) and G-G' (Figure 3-41) illustrate the approximately north–south configuration of occurrences of groundwater in the UHSU at IHSSs 119.1 and 119.2, respectively.

An examination of the stratigraphic cross sections (Figures 3-11 through 3-17) in conjunction with the hydrostratigraphic illustrations (Figures 3-35 through 3-41) depicts how bedrock topography, lithology, and overburden thickness help to localize the flow of groundwater. Uniform, uninterrupted groundwater flow exists only minimally at OU1 because of the lensing characteristics of the sedimentary beds. The conclusion to be drawn from these observations is that the UHSU is extremely heterogeneous. A conceptual model of groundwater at OU1 would resemble a network of paleochannels in the subsurface where groundwater in beds or zones of relatively high permeability are separated by barriers of bedrock and low permeability sediments and flow downgradient to a discharge point.

3.7.2 LHSU Data

The LHSU at OU1 comprises bedrock claystones (weathered and unweathered), siltstones, and silty sandstones of the upper Laramie Formation that are at depths greater than 25 feet below the bedrock contact. Bedding planes in the LHSU generally dip 1 to 2 degrees east (EG&G, 1992b). Generally, groundwater in the LHSU is confined, although locally there are indications that groundwater may exist under unconfined conditions.

Geotechnical analyses were performed on six samples collected from LHSU materials during the Phase III RFI/RI; Table 3-11 presents the results for these samples. Back-pressure permeabilities, which provide estimates of vertical hydraulic conductivities, range from 7.8 x 10^{-5} to 5.0 x 10^{-8} cm/sec for LHSU materials. The range of back-pressure permeabilities for the LHSU is smaller than the range for the UHSU and reflects more homogeneity in the types of material encountered. In samples collected at depths from 42 to 48 feet, grain sizes and the representative lithologies are siltstones with varying amounts of sand and clay; moisture contents range from 12 to 15.1%; and densities vary by 10%.

Generally, back-pressure permeabilities for claystone in the LHSU are approximately the same as back-pressure permeabilities for clays and weathered claystone in the UHSU (Tables 3-4, 3-5, and 3-11). In both the UHSU and LHSU, beds with significant sand content have higher permeabilities. The vertical distribution of back-pressure permeabilities in samples from the UHSU and LHSU is shown in Table 3-12.

During the Phase I and II RI, packer tests and single-well tests were conducted to determine hydraulic conductivities of bedrock materials; Table 3-13 presents results of these tests. Packer injection tests were conducted in 11 intervals: 3 tests in weathered claystone and siltstone units, 13 tests in unweathered claystone units, and 2 tests in sandstone units. Hydraulic conductivities ranged from 1×10^{-6} to 2×10^{-7} cm/sec for weathered claystone units, 9×10^{-7} to 1×10^{-8} cm/sec for unweathered claystone units, and 1×10^{-6} to 2×10^{-7} cm/sec for sandstone units (EG&G, 1990e). Single-well tests included drawdown recovery and slug injection tests. Drawdown recovery tests were conducted in two bedrock sandstone units, and slug injection tests were conducted in one bedrock sandstone unit. Data were evaluated using the same method for both types of tests. Hydraulic conductivities ranged from 7×10^{-5} to 3×10^{-6} cm/sec. The results of the single-well tests are roughly one order of magnitude higher than the results of the packer tests for bedrock sandstone units. This difference is attributed to better development of the aquifer during single-well tests and, conversely, injection of fine-grained material into the undeveloped borehole during packer injection tests (Rockwell, 1988b).

During the Phase III RFI/RI, packer tests were attempted and single-well tests were performed to determine hydraulic conductivities of LHSU materials. Appendix B1 describes the specific details of data collection, data analyses, and determination of hydraulic conductivities. Packer tests were not completed on LHSU materials due to conditions encountered during drilling and testing (e.g., borehole collapse and unsaturated conditions). Single-well tests were conducted in selected wells and piezometers after development, sampling, and water level stabilization. Table 3-14 presents the results of these tests. Hydraulic conductivities ranged from 3×10^{-5} to 5×10^{-7} cm/sec for weathered claystones and siltstones using the Bouwer and Rice (1976) method of analysis (see Appendix B1). This range of values is similar to the range of values for Phase I and II single-well tests.

Figure 3-42 summarizes all horizontal hydraulic conductivity values for UHSU and LHSU materials. The geometric mean values for claystones, regardless of whether they are UHSU or LHSU, are typically lower than mean values for UHSU materials that were tested, except for some colluvial samples. However, the hydraulic conductivities for sandstones approximate values for coarse-grained unconsolidated materials. This general trend indicates that the claystone and clay can severely restrict lateral and vertical movement of groundwater in the UHSU.

Prior to the Phase III RFI/RI investigation only four wells existed in bedrock materials of the LHSU (0387, 0587, 887, and 4587). During the Phase III RFI/RI, three additional bedrock monitoring wells (37891, 37991, and 39191) and one piezometer (39291) were installed in the LHSU. Appendix B3 presents water levels and hydrographs for OU1 monitoring wells. Seasonal variation in water levels is less for LHSU wells and piezometers than for UHSU wells and piezometers due to slow downward percolation rates and relatively small volumes of recharge and discharge in the LHSU. Table 3-15 presents water levels for January 1992, which represent dry season conditions for first quarter 1992. Wells 0387 and 0887 were damaged during the construction of the French Drain; therefore, data for these wells are not available.

The water level data for first quarter 1992 are plotted on Figure 3-43. Because the wells and piezometers are screened over different intervals, contour lines were not drawn between the data points, and gradients were not calculated. Water levels in LHSU bedrock wells and piezometers are more than 15 feet deeper than data obtained for wells screened in the UHSU.

Cross sections have been constructed to illustrate water levels in the bedrock of the LHSU at IHSSs 119.1 and 119.2. Figure 3-44 is a cross-section location map for the LHSU. Figure 3-45 is an east-west cross section in the vicinity of IHSS 119.1, and Figure 3-46 is a north-south cross section in the same area. The cross sections show that the groundwater in the LHSU wells is generally 5 to 15 feet below the UHSU/LHSU contact, indicating that there is poor hydraulic communication between the upper and lower units.

3.7.3 Assessment of Hydrogeological Conditions

Evaluation of the hydrogeologic data presented in previous sections indicates that the UHSU is variably saturated and that groundwater in this hydrogeological setting does not exist or move as it would within a typical continuous, homogeneous, shallow aquifer system. The following discussion evaluates and describes the hydrogeological conditions at OU1 including groundwater recharge, discharge, and flow for the UHSU and LHSU. Estimates of average horizontal groundwater flow velocities are provided to illustrate the different flow characteristics of the two HSUs. Volumetric estimates for the UHSU are included to show the amount of groundwater available for possible exploitation. Estimates of vertical average groundwater flow velocity between the UHSU and LHSU are provided to illustrate how the two groundwater systems interact. All calculated values are intended as "order-of-magnitude" estimates to provide reasonable quantitation of hydrogeological conditions.

3.7.3.1 UHSU Recharge and Discharge Characteristics

Recharge and discharge characteristics of the UHSU as well as the configuration of the bedrock surface and lithologic variability control the distribution of groundwater within this variably saturated unit. Sources of uniform recharge to the UHSU at OU1 include infiltration of incident precipitation and snowmelt (15 inches annually), although most incidental precipitation is lost; some to runoff, but largely to evapotranspiration due to dry climatological conditions; slow percolation rates (based on back pressure permeability test of surficial materials); and abundance of vegetation (Department of Agriculture, 1980). Surface water in the SID and portions of Woman Creek also provide localized surface recharge to the UHSU. Outfall from the Building 881 foundation drain was formerly a recharge source. The foundation drain is now connected to the French Drain. Potential future modifications to the RFP, including construction of surface water diversion canals and paving (which would reduce the area where infiltration could occur) could affect the amount of recharge to OU1.

Discharge from the UHSU occurs via evapotranspiration, which is enhanced by the south-facing orientation of the 881 Hillside area. Discharge also occurs at surface seeps, or at discharge boundaries such as Woman Creek, the bedrock surface, or the newly installed French Drain. At these boundaries, groundwater in the UHSU may be discharged as surface water and may travel as overland flow, reinfiltrate the UHSU at lower elevations, infiltrate into the bedrock or LHSU.

Surface seeps have been identified at 881 Hillside during recent field investigations. Surface water monitoring station SW046 is a surface seep located near the former skimming pond south of Building 881 (Figure 2-4). The water table was locally elevated in this area possibly due to recharge from the skimming pond. Another possible surface seep is located near IHSS 103. This area appeared wet throughout the Phase III RFI/RI field investigation and contained cattails and other water-tolerant vegetation. The water table is locally elevated in this area, possibly due to recharge from drainage ditches or leaking culverts that transport surface runoff. The culverts are located near the road in the vicinity of well 36191. The locations of these two surface seeps are generally coincident with the distribution of saturated UHSU materials (Figure 3-30).

Other seeps occur at the head region and along the margins of slumps. These seeps may be due to discharge or leakage of ponded water from bedrock depressions near the head region of associated slumps. A small area just southeast of well 37191 was observed to contain cattails and other water-loving vegetation during the Phase III RFI/RI field investigation and is indicative of a surface seep. This area is just downgradient of the groundwater high identified near well 37191. Similar wet, patchy areas containing cattails and other water-loving vegetation were noted north of Woman Creek north of well 38591 and just east of well 5587. In these areas, the colluvial water table intersects the ground surface because the bedrock surface is relatively shallow, resulting in surface seeps. The patchy nature of these surface seeps suggests that colluvial groundwater may preferentially flow along slump margins (Figure 3-28). The wet area around well 37191 is an example of a surface seep located at the head region of a slump and wet areas near Woman Creek are suggestive of seeps associated with slump margins.

3.7.3.2 UHSU Groundwater Flow

The saturated thickness map (Figure 3-31) shows that the UHSU groundwater flow paths presented in Figure 3-26 are oriented along north-south and northwest-southeast trending bedrock lows. These bedrock lows are typically associated with bedrock channels or lateral margins of slumps or with construction activities. The configuration of the water table and the bedrock surface suggests that groundwater flows downgradient in a series of unconnected channels, directed by the bedrock configuration and lithology changes.

If groundwater is present in bedrock channels in the UHSU, it may percolate into weathered bedrock of the UHSU. The clay-dominant lithologies and low vertical permeabilities of the UHSU and LHSU bedrock restrict the volume of water that can percolate from the UHSU to the LHSU. It is unknown to what degree weathering and fracturing in bedrock material may locally influence vertical flow. Fractures in weathered claystone may transmit groundwater or may be clogged with precipitate, which inhibits groundwater flow. Evidence concerning the disparity of hydraulic conductivities between relatively coarse-grained, unconsolidated material and clays and claystone is provided in the following discussion.

During French Drain excavation activities, sandy gravelly layers overlying bedrock were observed to be discharging groundwater into the trench (refer to Appendix A4), and UHSU groundwater was also observed in sandy and silty clay lenses bounded by denser UHSU clays or UHSU claystones (refer to Appendix A4). Dry zones were documented within bedrock materials directly below lenses of saturated alluvium. These observations indicate that UHSU groundwater preferentially flows southward and downgradient within these relatively coarser-grained horizons.

Little groundwater was observed in the UHSU bedrock materials, although some small amounts of seepage were observed in slump glide planes. The low seepage indicates that groundwater may preferentially reside in the potentially higher permeability glide planes, fractures, or disturbed materials associated with these slumps. The seepage from these zones is attributed to gravity drainage due to the localized release of geostatic pressure during excavation. Similarly, caliche zones were observed to bound some of these slump blocks, indicating that historical groundwater flow has occurred in these features, but has subsequently been reduced due to precipitation of caliche. The plasticity of the claystone may possibly permit healing of fractures or voids resulting from a disruptive event such as a slump. This healing capability is expected to inhibit groundwater flow in these potentially higher permeability zones.

3.7.3.3 UHSU Groundwater Flow Velocity

Estimates of average linear groundwater flow velocity were calculated for probable groundwater flow paths at IHSS 119.1 (Figure 3-26). Table 3-16 presents the values and calculation methods used. Hydraulic gradients were measured along the flow paths, and hydraulic conductivities were determined as the geometric mean of values resulting from well tests conducted in wells near the flow paths. Effective porosity values of 10% were used. This value is recognized as being applicable at OU1 (Hurr, 1976). In colluvial and fill materials south of Building 881 the average linear groundwater flow velocity is approximately 7.8 feet/year. For colluvial materials at IHSS 119.1, the average linear groundwater flow velocity is about 69 feet/year. Along the western reaches of Woman Creek, the average linear groundwater flow velocity is approximately 178 feet/year within the Valley Fill Alluvium. An average linear groundwater flow velocity was measured during the multiple-well and tracer tests (see Appendix B2), but the measured value is based on flow induced by pumping and is not considered applicable to this discussion. The average linear groundwater flow velocity for Valley Fill Alluvium is at least 23 times higher than average linear groundwater flow velocities determined for colluvium.

3.7.3.4 Volume of UHSU Groundwater

To better understand hydrogeological conditions within the UHSU, simple volume calculations were performed to estimate the volume of saturated UHSU materials, the volume of groundwater within saturated UHSU materials, and the potential yield from the UHSU. These estimates were derived for the OU1 area and for the area including OU1 downgradient to Woman Creek. The estimates for the volume of saturated UHSU materials were obtained by multiplying the area of saturation (from Figure 3-30) by a typical saturated thickness (from Figure 3-31). Because so few wells were completed in USHU bedrock, the volume calculations are based on the volume of saturated unconsolidated materials.

The volume of UHSU groundwater available for potential yield was estimated by multiplying the volume of saturated UHSU materials by an effective porosity of 0.1 as used in average linear groundwater velocity calculations. Table 3-17 presents the volume estimates.

For the OU1 area in January 1992, the volume of saturated UHSU materials is estimated to be 58 acre-feet. This is a high-range value obtained by including areas described as damp, but where actual data on saturation are lacking. The volume of groundwater available for potential movement or yield within OU1 is estimated at 5.8 acre-feet (or 1.89×10^6 gallons). In April 1992, the volume of saturated UHSU materials was estimated at 52 acre-feet calculated based on a saturated thickness map for this month (Figure 3-47). This decrease is largely due to the removal of the foundation drain as a source of recharge in the western part of OU1. The volume of groundwater available for potential movement or potential yield within OU1 was estimated at 5 acre-feet (or 1.63×10^6 gallons).

An evaluation of other aquifer parameters such as hydraulic conductivity and aquifer transmissivity indicates that it is questionable whether the estimated volume of water available for movement or yield could actually be extracted and replenished in a year. Driscoll (1989) states that if an aquifer has a transmissivity of less than 1,000 gallon per day per foot (gpd/ft) (1.4×10^{-4} square meters per second [m^2/sec]), it can supply only enough water for domestic wells or other low-yield uses. The transmissivity for the UHSU was obtained by multiplying the highest value of hydraulic conductivity for the UHSU colluvium from Phase III RFI/RI single-well tests (1×10^{-4} cm/sec) by the average aquifer thickness (4 feet). The resulting value of aquifer transmissivity for the UHSU is 1.2×10^{-6} m^2/sec. This value is approximately 100 times less than that identified as appropriate by Driscoll, and indicates that the UHSU at the 881 Hillside area would probably not be considered as an aquifer capable of being exploited for any reasonable use. Results of computer simulations of domestic water production capabilities from subsurface units beneath OU1 indicate values that are less than 45% of that required to supply a family of four (240 gallons per day). The computer simulations are included in Appendix F, Attachment F-1.

3.7.3.5 LHSU Recharge and Discharge Characteristics

Groundwater in saturated UHSU units percolates downward into the LHSU, but these recharge rates are expected to be very low. Recharge also occurs upgradient where the Laramie Formation crops out upgradient of OU1. Higher conductivity bedrock sandstone channels are expected to transmit water within the LHSU. Discharge from the LHSU is difficult to quantify, but is expected to be very low. Probable discharge boundaries exist at low elevations along the 881 Hillside area, but no data were collected to evaluate LHSU discharge because the prime focus of the Phase III RFI/RI investigation was the UHSU.

3.7.3.6 LHSU Groundwater Flow

Groundwater flow in the LHSU is difficult to characterize because the coarser-grained sandstones and siltstones that have been monitored are disconnected, and groundwater in these units is represented by discrete head levels. Because of this, no groundwater gradients were calculated for the LHSU. Nevertheless, as presented in Figure 3-43, potentiometric head levels in the LHSU below the central portions of the 881 Hillside area decline in a southerly direction toward Woman Creek.

3.7.3.7 LHSU Groundwater Flow Velocity

Because LHSU potentiometric head data exist only for discontinuous siltstone units, horizontal groundwater gradients and lateral groundwater flow velocities were not calculated. These calculations would have considerable uncertainty and are not germane to the following discussion.

Ideally configured well clusters do not exist to quantify downward movement of groundwater from the UHSU to the LHSU. However, vertical gradients were calculated at numerous well locations by comparing the water levels in UHSU wells to water levels at nearby LHSU monitoring wells and piezometers. Table 3-18 presents vertical hydraulic gradients calculated in the vicinity of IHSS 119.1. Estimated vertical hydraulic gradients range from 0.87 to 1.06 feet/foot. These relatively high vertical gradients indicate a strong potential for percolation from the UHSU to the LHSU. However, any downward movement of UHSU groundwater to the LHSU is controlled by lower permeability horizons within the LHSU and UHSU bedrock (Table 3-4 and 3-11).

To confirm this conclusion, average linear groundwater flow velocity in the vertical direction was calculated to estimate downward percolation from the UHSU to the LHSU in the vicinity of IHSS 119.1 (Table 3-19). Calculations were based on <u>UHSU</u> bedrock, as groundwater present in the colluvial materials encounters UHSU bedrock before LHSU bedrock. In fact, a comparison of Tables 3-11 and 3-4 shows that, of the three monitoring points in the vicinity of IHSS 119.1 for which permeability data were recorded for more than one interval (37891, 37991 and 39191), data from two wells indicate that selected bedrock intervals in the UHSU have lower values than LHSU intervals.

The geometric mean of the back-pressure permeability data from wells 37891 (depth 7.5 feet), 37891 (depth 10.4 feet), 37991 (depth 11 feet), 38991 (depth 21.4 feet), and piezometer 39191 (depth 12 feet), each sample from the UHSU, were used to calculate vertical flow velocity.

Primary effective porosity was 10%. The resulting average vertical linear groundwater velocity is 0.17 feet/year and 50 to 430 times less than the average horizontal groundwater velocity for saturated colluvial materials. This relationship between vertical and horizontal average linear groundwater velocities implies that there is a low rate of percolation from the UHSU to the LHSU and that groundwater in both HSUs would preferentially move horizontally near IHSS 119.1. These calculations do not account for flow through fractures, which is acknowledged to be a likely means of groundwater transport.

The high vertical gradients between the saturated UHSU and LHSU indicate a strong potential for infiltration, although the very low velocities indicate that little recharge of the LHSU from vertical percolation occurs.

3.7.3.8 French Drain IM/IRA

The evaluation of hydrogeological conditions at the 881 Hillside area was based in part on historical hydrogeological data, but predominantly on Phase III RFI/RI hydrogeological data collected during first and second quarters 1992. These data were shown to represent low water table conditions in January and high water table conditions in April at the 881 Hillside area. Since second quarter 1992, additional data have been collected under the continuing groundwater monitoring program at RFP and the French Drain IM/IRA program. Table 3-20 presents data from colluvial wells. Table 3-21 presents groundwater well data collected in early 1993, and Figure 3-48 is a groundwater level map constructed from these data, a year after the French Drain had been completed. These data were evaluated to support and confirm hydrogeological interpretations.

Available groundwater level data suggest that operation of the French Drain results in the presence of a new discharge boundary across the site that functions to reduce localized water levels. The westernmost and eastern areas directly south of the French Drain are dry. This is strong evidence that the French Drain is capable of capturing colluvial groundwater that has migrated from OU1. With respect to UHSU slump blocks, the French Drain was excavated to a depth where glide planes were no longer visible, so the system should capture groundwater migrating along these planes as well. Most groundwater monitoring wells located immediately downgradient (south) of the French Drain contained no groundwater (or groundwater below the bottom of the well screen) during April 1993. However, one well (10792, Figure 3-48) has contained groundwater above the bottom of the well screen during most of the period between January and July 1993, including April. This well is screened in a sandstone bed that was also noted during the excavation for the French Drain. It is possible this localized sandstone bed is continuous across and beneath the French Drain. This sandstone bed may be acting as a conduit transmitting bedrock groundwater under the French Drain. Alternatively, the source for the persistent groundwater in this well may be recharge from the SID located approximately 30 feet to the south. Even if the sandstone bed is permitting bedrock groundwater to bypass the French Drain, the potential for contaminant transport under the French Drain is limited. This portion of the French Drain is located remotely from known groundwater contaminant plumes (see Section 4.0). All of the known groundwater migration pathways and groundwater contaminant plumes along the French Drain allignment (Figure 4-24) appear to be effectively intercepted by the French Drain.

As part of the French Drain interception system, a large-diameter extraction well was installed in IHSS 119.1 and has been pumping since April 1993. In 1993, the well pumped 310 gallons from April to June, 75 gallons from July to September, and 75 gallons from October to December. The extraction of the limited volume of groundwater within the UHSU at this location is expected to significantly reduce the volume of groundwater in this area. This extraction of UHSU groundwater will limit the potential for flow of UHSU groundwater from the IHSS 119.1 area during the wet season.

3.7.4 Summary of the Shallow Hydrogeological System at OU1

The following conclusions will be used to support exposure assessment, risk assessment, and subsequent FS tasks:

- The UHSU at OU1 is not a typical aquifer, but rather a variably saturated water-bearing unit as a result of lithologic variations, bedrock configuration, and seasonal recharge. The conceptual model of groundwater flow at OU1 resembles subsurface paleochannels.

- Groundwater in the UHSU is present chiefly in the alluvial/colluvial materials, rather than bedrock. In the alluvium/colluvium, groundwater is localized near recharge areas and bedrock channels that contain thick sections (greater than 10 feet) of alluvial/colluvial section. In the UHSU bedrock, groundwater may be transmitted by glide planes that bound slump blocks and other occurrences of fracture porosity.

- Recharge through spring precipitation is an important factor in the occurrence of groundwater, as some areas are only seasonally saturated.

- The UHSU contains more groundwater in the western portion of OU1 than in the eastern portion. The chief source of groundwater was former discharge from the Building 881 foundation drain, which was rerouted in February 1992 to the French Drain collection system.

- Geotechnical and field test data indicate there is more variability in hydraulic conductivities of unconsolidated sediments than between unconsolidated material and bedrock. This confirms the strong role of lithology in directing and limiting groundwater flow.

- Geotechnical tests indicate that weathered claystones of the UHSU have about the same hydraulic conductivity of LHSU claystones. The vertical flow velocity of bedrock is estimated to be approximately 50 to 430 times less than the horizontal flow velocity of colluvial materials. This implies that except for fractures, groundwater flow from the UHSU alluvial/colluvial materials to the LHSU is limited.

- Before the French Drain became operational, complete groundwater flow paths existed in the UHSU from OU1 IHSSs to Woman Creek along channel-like features in the bedrock surface.

- Since the French Drain became operational, the volume of water in the UHSU at OU1 has diminished because of rerouting of the 881 Foundation Drain discharge to the French Drain.

- Based on the available data, the French Drain and accompanying extraction well in IHSS 119.1 appear to function as effective discharge boundaries and appear to intercept identified groundwater flow paths north of the SID.

3.8 ECOLOGY

Survey sites in both OU1 and a reference area were used to determine whether contamination resulting from activities in OU1 have, or could in the future, adversely affected ecological health. The reference area was used to provide specimens unlikely to be contaminated for comparison with OU1 specimens.

The physical area of OU1 was expanded to include downwind and down-drainage areas. This expanded area, designated as the OU1 ecological study area (referred to as "the study area"), allowed for examination of the continuum of potential contamination levels. The design allowed sampling of a variety of habitats in a potentially affected zone down-drainage and downwind from Building 881. The study area included OU1, the 881 Hillside area, and areas outside the industrial area boundary fence that extend west to the gravel access road, south to Woman Creek, and east to Pond C-2. Woman Creek formerly received surface water runoff from the industrial area, but construction of the SID between the industrial area and Woman Creek has diverted surface water flow to Pond C-2. Woman Creek may potentially be affected by groundwater seepage, windblown materials, and overflow from the SID.

Criteria for selection of the reference area included that the location be upwind and up drainage from 881 Hillside area activities and away from all other known RFP activities with the potential to produce contamination; have habitats as close to natural conditions as possible; and be an area unimpacted by other local industrial activities. The northwest portion of RFP, the Rock Creek watershed, met these criteria.

After study and reference areas were delineated, the terrestrial habitats (as identified in the SOPs) present within these areas were identified. Specific sample sites for terrestrial animal species were established within these habitats. Because of their concurrency, the OU1 EE was designed to use the database compiled during the baseline biological characterization of terrestrial and aquatic habitats investigation (DOE, 1992i). The locations of terrestrial sample sites in the study area and reference area are shown in Figures 2-12 and 2-13, respectively.

Study sites for the aquatic ecosystem were selected from stream and pond habitats in the Rock Creek and Woman Creek watersheds (Figure 2-14). Locations upstream from the study area on Woman Creek and locations on Rock Creek were used as reference sites. Study area sites were selected along Woman Creek downstream of OU1 and along the SID, including Pond C-2.

3.8.1 Terrestrial Ecosystem

The majority of the plant species at OU1 contributing to the terrestrial communities belong to 2 groups–vascular cryptograms (2 species) and vascular plants (217 species) (Figure 3-49). A complete list of all plant species documented at RFP is supplied in Appendix B of the *Baseline Biological Characterization of Terrestrial and Aquatic Habitats at the Rocky Flats Plant* (DOE, 1992i). Among the dominant vascular plants, various growth forms are represented. Trees and shrubs constituted 6% of the total number of species, forbs (broad-leaf herbs) 66%, graminoids (grasses and grass-like plants) 25%, and cactus 2%.

The flora of the entire RFP site are widely diverse due to varied geography, but reclamation activities (re-seeding) in the OU1 study area have limited the vegetation diversity of OU1. The OU1 study area comprises 4% of the total area of RFP. Although 13 vegetative habitats are represented in OU1, 2 grassland habitats (mesic mixed grassland and reclaimed) are dominant, representing about 82% of the total area. Another 9% of the area is either developed or disturbed. Marsh habitats (tall marsh, short marsh, and open water) occupy about 4%, woodland habitat (primarily riparian) constitutes another 4%, and shrub habitats (short and bottomland shrub) account for the remaining area.

Wildlife species at RFP are typical of those in similar habitats throughout the foothills area because of the absence of barriers between the western plains and the surrounding foothill terrain. Wildlife habitat at RFP is characterized according to plant communities upon which wildlife depend for food and shelter, as outlined in the baseline report (DOE, 1992i).

3.8.2 Aquatic Ecosystem

The aquatic ecosystem at OU1 includes two major habitat types: streams and ponds. Neither is well developed due to the semiarid climate and seasonal distribution of rainfall that occurs along the Colorado Front Range. The Woman Creek channel west of Pond C-1 and east of Pond C-2 is essentially in native condition. The ponds and the SID represent significant alteration of the natural drainage. As a result of limited and inconsistent surface water supplies, aquatic species with short life cycles and smaller habitat requirements, such as benthic macroinvertebrates, have developed more diverse communities than fish. Fish are limited by intermittent streamflow, water temperature fluctuations, food, and habitat. During the annual low rainfall periods, habitat availability in the intermittent reaches of the Woman Creek watershed within the OU1 study area limits the number of life forms in the aquatic ecosystem.

Table 3-1

Wind Direction Frequency (Percent) by Four Wind-Speed Classes* (Page 1 of 1)

Fifteen-Minute Averages - 1990 through 1991

	Calm	1-3 m/s (2-7 mi/hr)	3-7 m/s (7-16 mi/hr)	7-15 m/s (16-34 mi/hr)	>15 m/s (>34 mi/hr)	TOTAL
—	3.40					3.40
N	0.00	2.86	3.85	0.47	0.00	7.18
NNE	0.00	2.89	2.69	0.20	0.00	5.79
NE	0.00	2.82	1.50	0.03	0.00	4.35
ENE	0.00	2.21	0.77	0.01	0.00	2.99
E	0.00	2.55	0.72	0.01	0.00	3.27
ESE	0.00	2.49	1.12	0.00	0.00	3.62
SE	0.00	2.72	2.38	0.06	0.00	5.17
SSE	0.00	2.50	2.40	0.21	0.00	5.11
S	0.00	2.57	2.57	0.17	0.00	5.32
SSW	0.00	2.37	2.21	0.15	0.00	4.73
SW	0.00	2.30	3.12	0.19	0.00	5.61
WSW	0.00	2.56	4.07	0.81	0.01	7.46
W	0.00	3.17	3.18	2.29	0.39	9.03
WNW	0.00	3.04	4.27	4.23	0.33	11.87
NW	0.00	3.00	4.34	1.34	0.01	8.69
NNW	0.00	2.53	3.65	0.23	0.00	6.41
TOTALS	3.40	42.58	42.85	10.41	0.75	100.00

* See wind rose in Figure 3-3.
m/s = Meters per second
mi/hr = Miles per hour

N = North
E = East
S = South
W = West

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Table 3-2

Surface Water Flow Rates (cfs) (1990)

Surface Water Station	Location	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
SW029	Seep	—	.38	—	<.1	<.1	No flow	—	—	No flow
SW031	South Interceptor Ditch	0.07	<0.1	No flow	—	—	No flow	No flow	No flow	No flow
SW032	Woman Creek	—	.28	—	<.1	.104	.125	.14	No flow	No flow
SW033	Woman Creek	—	.21	.29	.24	—	.07	—	No flow	No flow
SW034	Woman Creek	—	.06	.008	—	No flow	No flow	—	No flow	No flow
SW035	South Interceptor Ditch	—	—	No flow	—	No flow	No flow	No flow	No flow	No flow
SW036	South Interceptor Ditch	—	No flow	—	—	No flow	—	—	No flow	—
SW038	Surface Water	—	—	—	—	—	—	—	—	No flow
SW039	Near western confluence, Woman Creek	—	.12	.42	.25	.23	No flow	No flow	—	No flow
SW044	Skimming Pond Discharge	No flow	No flow	No flow	—	No flow	No flow	—	No flow	No flow
SW045	881 Foundation Drain	No flow	No flow	—	—	No flow	—	—	—	—
SW046	Seep	—	—	—	—	—	—	—	No flow	No flow
SW066	South Interceptor Ditch	No flow	—	—	—	No flow	—	No flow	—	—
SW067	South Interceptor Ditch	No flow	No flow	—	—	No flow	—	No flow	—	—
SW068	South Interceptor Ditch	No flow	No flow	—	—	No flow	No flow	—	No flow	—
SW069	South Interceptor Ditch	No flow	No flow	—	—	—	—	No flow	No flow	No flow
SW070	South Interceptor Ditch	No flow	No flow	—	—	No flow	—	No flow	—	No flow
SW071	Seep	—	No flow	—	—	—	—	—	—	—
SW072	Seep	—	No flow	—	—	—	—	—	—	—
SW125	Seep	—	—	—	—	—	—	—	—	No flow
SW126	Seep Ditch	—	No flow	—	—	—	—	—	—	—

— = No data available.

Table 3-3 Soil Types at Operable Unit No. 1

Series	Family	Phase	Minimum-Maximum Slope (%)	Infiltration Rate	Soil Type*
Denver-Kutch-Midway	Torrertic Argiustolls	clay loam	9-25	slow	31
Flatirons	Aridic Paleustolls	very cobbly sandy loam	0-3	slow	45
Haverson	Ustic Torrifluvents	loam	0-3	slow	60
Nederland	Aridic Argiustolls	very cobbly sandy loam	15-50	moderate	100

* Soil type number corresponds to soil type in Figure 3-6.

Table 3-4

Upper Hydrostratigraphic Unit Geotechnical Results - Phase III RFI/RI (Page 1 of 3)

Borehole Number/ Sample Number	Test Interval (feet below ground surface)	Grain Size (%)			Lithologic Name	Atterberg Limits	USCS	Moisture Content (% dry wt)	Dry Density (lb/ft³)	Wet Density (lb/ft³)	Back-Pressure Permeability (cm/sec)[1]	Specific Gravity
		Sand	Silt	Clay		Liquid Limit / Plastic Limit / Plastic Index						
37391/BH00648EBU1	2.55-2.80	--	--	--	--	--	--	22.1	98.8	120.6	$8.1x10^{-9}$	--
37391/BH00661EBU1	2.20-2.55	44	19	37	Silty sandy clay	52.8/22.6/30.2	CH	--	--	--	--	--
37391/BH00660EBU1	11.00-11.75	27	27	46	Silty sandy clay	48.8/17.1/31.7	CL	--	--	--	--	--
37391/BH00658EBU1	11.75-12.00	--	--	--	--	--	--	25.8	103.0	129.6	$2.5x10^{-9}$	--
37491/BH00570EBU1	2.70-3.00	--	--	--	--	--	--	17.4	113.2	132.9	$1.7x10^{-8}$	--
37491/BH00571EBU1	3.00-3.25	44	26	30	Silty sandy clay	37.3/15.1/22.2	CL	--	--	--	--	--
37591/BH00665EBU1	3.00-3.25	38	13	49	Silty sandy clay	57.3/25.0/32.8	CH	--	--	--	--	--
37591/BH00664EBU1	3.25-3.50	--	--	--	--	--	--	24.9	96.3	120.3	$5.9x10^{-6}$	--
37591/BH00671EBU1	6.95-7.45	64	11	25	Silty clayey sand	43.8/15.4/28.4	SC	--	--	--	--	--
37591/BH00670EBU1	7.45-7.70	--	--	--	--	--	--	12.6	114.0	128.3	$1.3x10^{-5}$	--
37691/BH00592EBU1	7.40-7.55	78	11	11	Silty clayey sand	36.2/16.7/19.5	SM	--	--	--	--	--
37691/BH00591EBU1	7.55-7.80	--	--	--	--	--	--	N/A	N/A	N/A	N/A	--
37691/BH00596EBU1	13.50-13.80	56	14	30	Silty clayey sand	43.8/19.4/24.4	SC	--	--	--	--	--
37691/BH00595EBU1	13.80-14.00	--	--	--	--	--	--	18.4	111.0	131.4	$3.7x10^{-8}$	--
37891/BH00712EBU1	0.80-1.10	33	22	45	Silty sandy clay	54.4/20.5/33.9	CH	--	--	--	--	--

N/A = Information not available
cm/sec = Centimeters per second
lb/ft³ = Pounds per cubic foot
USCS = Unified Soil Classification System
CH = Fat clay
CL = Lean clay
ML = Silt
SC = Clayey sand
SM = Silty sand
SW = Clean sand
* = Samples from UHSU. Well is completed in LHSU.

1 Values of back-pressure permeability also presented in Table 3-11

Table 3-4

Upper Hydrostratigraphic Unit Geotechnical Results - Phase III RFI/RI (Page 2 of 3)

Borehole Number/ Sample Number	Test Interval (feet below ground surface)	Grain Size (%) Sand	Silt	Clay	Lithologic Name	Atterberg Limits Liquid Limit/Plastic Limit/Plastic Index	USCS	Moisture Content (% dry wt)	Dry Density (lb/ft^3)	Wet Density (lb/ft^3)	Back-Pressure Permeability (cm/sec)[1]	Specific Gravity
37891/BH00711EBU1	1.10-1.35	--	--	--	--	--	--	13.3	107.4	121.6	$1.8x10^{-7}$	--
37991/BH00720EBU1	3.00-3.50	06	13	81	Clay	58.1/20.5/37.6	CH	--			--	--
37991/BH00719EBU1	3.50-3.75	--	--	--	--	--	--	15.2	113.5	130.8	$1.3x10^{-8}$	--
38591/BH00812EBU1	4.80-5.05	82	11	7	Sand	20.9/15.9/5.0	SM	--	--	--	--	2.72
38591/BH00811EBU1	5.05-5.30	--	--	--	--	--	--	N/A	N/A	N/A	N/A	--
38991/BH00833EBU1	1.50-1.75	43	19	38	Silty sandy clay	50.8/19.7/31.1	CH	--	--	--	--	2.75
38991/BH00832EBU1	1.75-2.00	--	--	--	--	--	--	14.5	97.7	111.9	$1.7x10^{-5}$	--
38991/BH00840EBU1	11.50-11.75	24	24	52	Sandy silty clay	43.5/15.0/28.5	CL	--	--	--	--	2.70
38991/BH00839EBU1	11.75-12.00	--	--	--	--	--	--	10.1	114.2	125.8	$5.1x10^{-8}$	--
39091/BH00753EBU1	0.50-0.90	93	03	04	Sand	N/A	SW	--	--	--	--	2.68
39091/BH00752EBU1	0.90-1.15	--	--	--	--	--	--	8.2	97.9	105.9	$1.2x10^{-3}$	--
39191/BH00761EBU1	3.00-3.25	11	16	73	Sandy silty clay	62.6/22.2/40.4	CH	--	--	--	--	2.78
39191/BH00760EBU1	3.25-3.50	--	--	--	--	--	--	21.0	102.1	123.6	$2.1x10^{-8}$	--
39691/BH00866EBU1	5.00-5.25	28	29	43	Sandy silty clay	34.3/12.5/21.8	CL	--	--	--	--	2.71
39691/BH00865EBU1	5.25-5.50	--	--	--	--	--	--	17.4	109.5	128.6	$7.6x10^{-7}$	--

N/A = Information not available
cm/sec = Centimeters per second
lb/ft^3 = Pounds per cubic foot
USCS = Unified Soil Classification System
CH = Fat clay
CL = Lean clay
ML = Silt
SC = Clayey sand
SM = Silty sand
SW = Clean sand
* = Samples from UHSU. Well is completed in LHSU.

1 Values of back-pressure permeability also presented in Table 3-11

Table 3-4

Upper Hydrostratigraphic Unit Geotechnical Results - Phase III RFI/RI (Page 3 of 3)

Borehole Number/ Sample Number	Test Interval (feet below ground surface)	Grain Size (%) Sand	Silt	Clay	Lithologic Name	Atterberg Limits Liquid Limit/Plastic Limit/Plastic Index	USCS	Moisture Content (% dry wt)	Dry Density (lb/ft^3)	Wet Density (lb/ft^3)	Back-Pressure Permeability (cm/sec)[1]	Specific Gravity
*37891/BH00716EBU1	7.20-7.50	27	26	47	Silty sandy claystone	57.5/23.6/33.9	--	--	--	--	--	
*37891/BH00715EBU1	7.50-7.75	--	--	--	--	--		21.5	99.5	121.0	$3.8x10^{-8}$	--
*37891/BH00738EBU1	10.00-10.20	02	16	82	Claystone	61.5/24.5/37.0	--	--	--	--	--	2.69
*37891/BH00737EBU1	10.20-10.45	--	--	--	--	--		21.7	100.6	122.5	$4.7x10^{-8}$	--
*37991/BH00724EBU1	11.10-11.40	3	17	80	Claystone	65.2/22.7/42.5	--	--	--	--	--	--
*37991/BH00723EBU1	11.40-11.65	--	--	--	--	--		22.7	103.4	126.8	$5.5x10^{-9}$	--
38991/BH00845EBU1	20.90-21.15	02	21	77	Silty claystone	64.9/23.4/41.5	--	--	--	--	--	2.76
38991/BH00844EBU1	21.15-21.40	--	--	--	--	--		21.4	106.4	129.2	$4.2x10^{-9}$	--
*39191/BH00766EBU1	11.50-11.75	10	43	47	Sandy silty claystone	39.7/15.8/23.9	--	--	--	--	--	2.64
*39191/BH00765EBU1	11.75-12.00	--	--	--	--	--		12.0	124.0	138.9	$9.5x10^{-8}$	--

N/A = Information not available
cm/sec = Centimeters per second
lb/ft^3 = Pounds per cubic foot
USCS = Unified Soil Classification System
CH = Fat clay
CL = Lean clay
ML = Silt
SC = Clayey sand
SM = Silty sand
SW = Clean sand
* = Samples from UHSU. Well is completed in LHSU.

1 Values of back-pressure permeability also presented in Table 3-11

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Table 3-5

Upper Hydrostratigraphic Unit Geotechnical Results — French Drain Geotechnical Investigation (Page 1 of 1)

Borehole Number	Interval of Packer Test (feet below ground surface)	Permeability of Packer Test (cm/sec)	Field Lithology Description	Interval of Back-Pressure Permeability Test (feet below ground surface)	Back-Pressure Permeability Test (cm/sec)	Grain Size Analysis Results
B300690	14.98-20.25	$<3.7x10^{-6}$	Claystone and silty sandstone	18.5-19.0	$1.6x10^{-7}$	N/A
B300790	17.0-23.0	$<4.8x10^{-6}$	Claystone	18.6-18.8	$6.0x10^{-9}$	N/A
B301090	25.03-30.3	N/A	claystone	25.5-26.0	$3.1x10^{-8}$	N/A
B301190	23.0-28.0	$<6.6x10^{-6}$	Claystone and clayey siltstone	23.6-24.0	$2.4x10^{-8}$	Sandy siltstone
B301190	34.0-39.0	$<3.5x10^{-6}$	Claystone and siltstone	35.0-35.5	$1.1x10^{-8}$	Sandy clayey siltstone
B301390	N/A	N/A	Sandy claystone and silty sandstone	23.8-24.4	$1.9x10^{-7}$	Clayey siltstone
B301490	27.5-32.77	$<2.3x10^{-6}$	Claystone	28.3-28.6	$3.1x10^{-8}$	N/A
B301590	26.3-30.3	$8.0-10^{-6}$	Claystone and sandstone	26.75-27.1	$1.5x10^{-6}$	Silty Sandstone
B301690	24.75-32.9	$<4.3x10^{-7}$	Claystone, siltstone, and sandstone	29.6-30.0	$2.4x10^{-8}$	Clayey siltstone
B301690	32.9-37.8	$<4.x10^{-7}$	Claystone, sandstone, and siltstone	32.4-32.7	$7.1x10^{-8}$	Sandy siltstone
B301990	26.6-31.6	$<5.4x10^{-7}$	Sandy claystone	29.6-30.3	$7.0x10^{-8}$	Sandy clayey siltstone
B303790	27.0-32.0	$<5.4x10^{-7}$	Silty claystone	30.8-31.5	$4.0x10^{-8}$	Clayey siltstone

Source (EG&G, 1990i)

N/A = Not applicable

Table 3-6

Upper Hydrostratigraphic Unit Hydraulic Conductivity Estimates — Single-Well Tests Phase I and II RI (Page 1 of 1)

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Upper HSU Classification
5686	$2x10^{-3}$	Drawdown/recovery	--	Woman Creek valley-fill alluvium
5986	$3x10^{-4}$	Drawdown/recovery	19.0-28.00	Sandstone
6586	$3x10^{-3}$	Drawdown/recovery	2.5-8.0	Woman Creek valley-fill alluvium
6886	$1x10^{-3}$	Drawdown/recovery	1.5-3.5	Woman Creek valley-fill alluvium
6986	$5x10^{-4}$	Drawdown/recovery	3.0-14.0	Colluvium
6986	$2x10^{-4}$	Slug test	3.0-14.0	Colluvium
7086	$9x10^{-4}$	Drawdown/recovery	--	Woman Creek valley-fill alluvium
0287	$4x10^{-5}$	Drawdown/recovery	3.22-9.08	Colluvium
	$3x10^{-5}$	Slug test	3.22-9.08	Colluvium
0487	$5x10^{-4}$	Drawdown/recovery	3.51-19.47	Colluvium
0587 BR	$2x10^{-6}$	Packer	26.4-36.1	Weathered claystone
6286 BR	$3x10^{-5}$	Drawdown/recovery	N/A	Sandstone
	$6x10^{-6}$	Slug	N/A	Sandstone

cm/sec = Centimeters per second
-- = unavailable
HSU = hydrostratigraphic unit
[1]Hydraulic conductivity values also presented in Figure 3-42.

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Table 3-7

Upper Hydrostratigraphic Unit Hydraulic Conductivity Estimates — Single-Well Tests Phase III RFI/RI (Page 1 of 1)

Well/ Piezometer Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithologic Description	Upper HSU Classification
34791	$1x10^{-5}$ $6x10^{-6}$	Slug injection/ slug withdrawal	6.2-7.7	Sand and gravel	Colluvium
35691	$1x10^{-6}$ $9x10^{-7}$	Slug injection/ slug withdrawal	15.8-26.4	Silt, clay, and gravel	Disturbed colluvium
36191	$1x10^{-6}$	Bail down/recovery	9.7-14.4	Sand and gravel	Disturbed colluvium
37191	$1x10^{-4}$ $4x10^{-5}$	Slug injection/ slug withdrawal	11.3-20.9	Gravelly, sandy clay	Colluvium
37591	$7x10^{-6}$	Bail down/recovery	7.8-12.4	Gravel, sand, and clay	Rocky Flats Alluvium
38191	$1x10^{-5}$ $2x10^{-6}$	Slug injection/ slug withdrawal	10.1-14.9	Sand, silt, clay, and gravel	Colluvium
38591	$4x10^{-4}$	Bail down/recovery	5.9-7.5	Silty sand with clay and gravel	Woman Creek valley-fill alluvium
31891	$2x10^{-4}$ $2x10^{-4}$	Slug injection/ slug withdrawal	16.8-18.4	Sandy claystone, clayey sandstone	Bedrock sandstone
38991	$1x10^{-6}$	Bail down/recovery	27.0-36.6	Claystone, silt stone	Weathered claystone, siltstone
*39191	$1.7x10^{-6}$ $(3.3x10^{-6})$	Packer	17.6-26.8	Claystone with varying amounts of silt	Weathered claystone

Note: Low water levels at 37791 prevented estimates of hydraulic conductivity measurements from bail down/recovery tests.
cm/sec = centimeters per second
HSU = hydrostratigraphic unit
[1]Hydraulic conductivity values also presented in Figure 3-42
* Test in UHSU. Well completed in LHSU.

Table 3-8

Upper Hydrostratigraphic Unit Hydraulic Conductivity Estimate— French Drain Geotechnical Investigation (Page 1 of 4)

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithology Classification	Comments
B300190	$<1.5\times10^{-6}$	Packer	18.8-25.1	Claystone and siltstone	
B300290	2.2×10^{-3}	Packer	14.9-21.2	Claystone and siltstone	
	2.3×10^{-3}	Packer	18.1-24.3	Silty claystone	
B300590	$<2.8\times10^{-6}$	Packer	9.7-15.0	Clay and claystone	No water loss
	$<3.7\times10^{-6}$	Packer	14.8-20.0	Silty claystone	No water loss
	$<4.5\times10^{-6}$	Packer	17.1-22.4	Silty claystone	No water loss
B300690	3.3×10^{-6}	Packer	10.1-15.4	Clay, claystone and siltstone	No water loss
	3.7×10^{-6}	Packer	15.0-20.2	Claystone and siltstone	No water loss
	8.4×10^{-7}	Packer	20.1-25.4	Claystone, siltstone and sandstone	
B300790	$<5.0\times10^{-6}$	Packer	10.1-13.0	Claystone and sandstone	No water loss
	$<8.4\times10^{-6}$	Packer	13.0-17.0	Silty claystone	No water loss
	$<4.8\times10^{-6}$	Packer	17.0-23.0	Claystone	No water loss
B300890	$<5.9\times10^{-6}$	Packer	16.3-19.5	Claystone	No water loss
	$<3.4\times10^{-6}$	Packer	19.5-25.0	Silty claystone	No water loss
	2.0×10^{-6}	Packer	24.5-29.5	Silty claystone and claystone	
B300990	$<2.6\times10^{-6}$	Packer	14.3-19.3	Claystone	No water loss
	$<1.3\times10^{-6}$	Packer	19.3-24.3	Claystone	No water loss
	$<2.0\times10^{-6}$	Packer	24.3-29.3	Claystone	No water loss
B301090	$<6.4\times10^{-6}$	Packer	22.1-27.3	Claystone	No water loss

(Source: EG&G 1990e)

[1] Hydraulic conductivity values also presented in Figure 3-42.
< = denotes no water loss during test and value is estimated upper bound

Table 3-8

Upper Hydrostratigraphic Unit Hydraulic Conductivity Estimate— French Drain Geotechnical Investigation (Page 2 of 4)

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithology Classification	Comments
B301190	$<6.6\times10^{-6}$	Packer	23.0-28.0	Claystone and clayey siltstone	No water loss
	$<5.3\times10^{-6}$	Packer	28.0-33.0	Claystone and siltstone	No water loss
	$<3.5\times10^{-6}$	Packer	34.0-39.0	Claystone and siltstone	No water loss
B301290	$<1.5\times10^{-6}$	Packer	9.5-14.5	Claystone	No water loss
	$<1.0\times10^{-6}$	Packer	14.5-19.5	Claystone	No water loss
	1.1×10^{-4}	Packer	19.5-24.5	Sandy claystone	
B301390	3.5×10^{-6}	Packer	14.8-18.8	Claystone	
	1.7×10^{-7}	Packer	18.8-23.8	Claystone and silty sandstone	
	3.5×10^{-6}	Packer	24.8-28.8	Claystone and silty sandstone	
	$<5.0\times10^{-7}$	Packer	28.8-33.8	Claystone	No water loss
B301490	$<4.9\times10^{-6}$	Packer	18.0-23.3	Claystone	No water loss
	$<6.0\times10^{-6}$	Packer	22.7-28.0	Claystone, siltstone, and sandstone	No water loss
	$<2.3\times10^{-6}$	Packer	27.5-32.8	Claystone	No water loss
B301590	8.5×10^{-4}	Packer	16.5-20.3	Claystone	
	4.2×10^{-5}	Packer	20.3-25.3	Claystone and siltstone	
	2.3×10^{-6}	Packer	25.3-30.3	Claystone and sandstone	
	8.0×10^{-6}	Packer	26.3-30.3	Claystone and sandstone	
B301690	$<6.6\times10^{-7}$	Packer	22.8-27.6	Claystone and siltstone	No water loss
	$<4.3\times10^{-7}$	Packer	24.7-32.9	Claystone, siltstone and sandstone	No water loss
	4.4×10^{-7}	Packer	32.9-37.8	Claystone, siltstone, and sandstone	

(Source: EG&G 1990e)

[1] Hydraulic conductivity values also presented in Figure 3-42.
< = denotes [illegible] water loss during test and value is estimated upper bound

Table 3-8

Upper Hydrostratigraphic Unit Hydraulic Conductivity Estimate— French Drain Geotechnical Investigation (Page 3 of 4)

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithology Classification	Comments
B301790	$<1.3\times10^{-6}$	Packer	22.8-24.6	Claystone	No water loss
	$<5.8\times10^{-7}$	Packer	24.6-29.6	Sandy claystone	No water loss
	$<4.8\times10^{-7}$	Packer	29.6-34.6	Claystone	No water loss
	$<4.1\times10^{-7}$	Packer	34.6-39.6	Claystone	No water loss
B301890	$<8.3\times10^{-7}$	Packer	23.5-26.9	Claystone	No water loss
	3.9×10^{-6}	Packer	26.9-31.9	Claystone and siltstone	
	$<4.5\times10^{-7}$	Packer	31.9-36.9	Claystone and siltstone	No water loss
	$<4.5\times10^{-7}$	Packer	37.9-41.9	Claystone	No water loss
B301990	$<7.4\times10^{-7}$	Packer	22.6-26.6	Silty claystone	No water loss
	$<5.4\times10^{-7}$	Packer	26.6-31.6	Sandy claystone	No water loss
	$<5.6\times10^{-7}$	Packer	31.6-36.6	Silty claystone	No water loss
	$<5.3\times10^{-7}$	Packer	38.6-41.6	Silty claystone	No water loss
B302090	$<7.2\times10^{-7}$	Packer	29.0-32.0	Silty claystone	No water loss
	$<5.5\times10^{-7}$	Packer	32.0-37.0	Silty claystone	No water loss
	$<5.2\times10^{-7}$	Packer	33.0-37.0	Silty claystone	No water loss
	$<4.5\times10^{-7}$	Packer	38.0-42.0	Silty claystone	No water loss
B302190	$<6.2\times10^{-7}$	Packer	32.0-35.2	Claystone	No water loss
	$<4.2\times10^{-7}$	Packer	35.2-40.0	Claystone	No water loss
	$<3.6\times10^{-7}$	Packer	40.0-45.0	Claystone and siltstone	No water loss
B302290	$<7.4\times10^{-7}$	Packer	23.0-27.0	Claystone	No water loss
	$<5.4\times10^{-7}$	Packer	27.0-32.0	Claystone	No water loss
	$<4.5\times10^{-7}$	Packer	32.0-37.0	Claystone	No water loss

(Source: EG&G 1990e)

[1] Hydraulic conductivity values also presented in Figure 3-42.
< = denotes no water loss during test and value is estimated upper bound

Table 3-8

Upper Hydrostratigraphic Unit Hydraulic Conductivity Estimate— French Drain Geotechnical Investigation (Page 4 of 4)

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithology Classification	Comments
B303790	$<8.2\text{x}10^{-7}$	Packer	17.0-22.0	Silty claystone	No water loss
	$<6.6\text{x}10^{-7}$	Packer	22.0-27.0	Claystone	No water loss
	$<5.4\text{x}10^{-7}$	Packer	27.0-32.0	Silty claystone	No water loss
B303890	$<1.2\text{x}10^{-6}$	Packer	14.0-18.0	Claystone	No water loss
	$<1.0\text{x}10^{-6}$	Packer	20.0-23.0	Claystone	No water loss
	$<6.2\text{x}10^{-7}$	Packer	23.0-28.0	Claystone	No water loss

(Source: EG&G 1990e)

[1] Hydraulic conductivity values also presented in Figure 3-42.
< = denotes no water loss during test and value is estimated upper bound

Table 3-9

Upper Hydrostratigraphic Unit Water Levels (January 1992)

Location	Bottom of Screen (feet above MSL)	Contact Elevation (feet above MSL)	Top of Casing (feet above MSL)	Water Level Below Top of Casing	Groundwater Elevation (feet above MSL)	Saturated Thickness* (feet)
0974	NR	NR	5926.25	9.81	5916.44	NR
1074	NR	NR	5925.91	9.31	5916.60	NR
5886	5891.71	5892.21	5897.65	6.05	5891.60	BBS
6286	5866.81	5875.54	5903.18	27.38	5875.8	CBD
6386	5885.84	5886.29	5902.01	NA	NA	NA
6486	5830.06	5830.56	5841.05	8.44	5832.61	2.55
6886	5884.47	5885.17	5890.49	3.71	5886.78	2.31
6986	5907.46	5906.96	5922.52	3.85	5918.67	11.21
0187	5980.66	5980.62	5994.08	7.99	5986.09	5.43
0487	5890.32	5890.29	5911.58	14.39	5897.19	6.90
4387	5912.81	5913.06	5926.41	10.08	5916.33	3.52
4487	5946.13	5946.43	5951.10	DRY	DRY	DRY
4787	5875.51	5873.76	5884.64	9.45	5875.19	BBS
4887	5899.62	5899.67	5911.41	NA	NA	NA
4987	5907.91	5903.66	5914.27	NA	NA	NA
5087	5919.64	5920.64	5934.78	NA	NA	NA
5187	5949.43	5950.77	5965.22	15.51	5949.71	.28
5287	5947.60	5947.85	5969.57	9.67	5959.90	12.3
5387	5950.94	5949.99	5961.81	4.99	5956.82	5.88

Table 3-9 (Continued)

Upper Hydrostratigraphic Unit Water Levels (January 1992)

Location	Bottom of Screen (feet above MSL)	Contact Elevation (feet above MSL)	Top of Casing (feet above MSL)	Water Level Below Top of Casing	Groundwater Elevation (feet above MSL)	Saturated Thickness* (feet)
5487	5951.32	5951.85	5957.62	3.29	5954.33	3.01
5587	5852.74	5852.89	5858.39	NA	NA	NA
B301889	5844.20	5844.50	5868.83	DRY	DRY	DRY
B302089	5894.2	5894	5909.55	16.02	5893.35	BBS
30991	5839.42	5840.32	5851.82	NA	NA	NA
31491	5883.68	5886.08	5905.03	NA	NA	NA
31891	5898.32	5999.7	5919.52	18.39	5901.13	2.81
31791	5865.26	5868.26	5879.80	15.91	5863.89	BBS
32591	5898.36	5898.96	5917.41	18.90	5898.51	.15
33491	5917.37	5918.01	5928.59	NA	NA	NA
33691	5918.88	5919.19	5929.24	NA	NA	NA
33891	5918.84	5919.44	5929.94	NA	NA	NA
34591	5943.29	5943.99	5954.63	NA	NA	NA
34791	5943.39	5943.39	5953.91	5.27	5948.64	5.25
35391	5952.42	5954.00	5963.03	12.35	5950.68	BBS
35691	5912.20	5913.56	5941.36	12.05	5929.31	17.11
35991	5959.55	5961.10	5976.45	19.08	5957.37	BBS
36191	5948.29	5948.89	5965.17	11.83	5953.34	5.05
[illegible]6391	5937.16	5938.17	5967.0[illegible]	31.68	5935.33	BBS

Table 3-9 (Continued)

Upper Hydrostratigraphic Unit Water Levels (January 1992)

Location	Bottom of Screen (feet above MSL)	Contact Elevation (feet above MSL)	Top of Casing (feet above MSL)	Water Level Below Top of Casing	Groundwater Elevation (feet above MSL)	Saturated Thickness* (feet)
36691	5923.93	5924.76	5951.52	27.95	5923.57	BBS
36991	5960.86	5961.48	5972.31	NA	NA	NA
37191	5924.84	5925.36	5948.29	10.02	5938.27	13.43
37591	5978.82	5979.42	5993.45	10.41	5983.04	4.22
37691	5967.96	5968.26	5985.24	NA	NA	NA
37791	5981.56	5982.16	6004.18	21.63	5982.55	.99
38191	5909.47	5909.82	5926.40	10.29	5916.11	6.6
38291	5915.79	5916.09	5926.71	NA	NA	NA
38591	5857.06	5857.47	5866.62	8.55	5858.07	1.01
38891	5881.96	5882.26	5893.24	NA	NA	NA
38991	5856.28	5873.58	5895.49	28.91	5866.58	CBD
39691	5997.26	5999.46	6008.37	10.10	5998.27	1.01

* - Saturated thickness presented is saturated interval above base of the screen.
NR - No record available.
MSL - Mean Sea Level.
BBS - Denotes measured water level was below the bottom of the screen.
NA - Not available for measurement.
CBD - Cannot be determined.

Table 3-10

Upper Hydrostratigraphic Unit Water Levels January through July 1992 (Page 1 of 4)

Location	Groundwater Elevation and Saturated Thickness by Month[1]													
	January		February		March		April		May		June		July	
	*Elev.	**Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.
0974	5916.44	NR	5916.58	NR	NA	NA	5918.51	NR	5917.68	NR	Abandoned		NA	NA
1074	5916.60	NR	5917.11	NR	NA	NA	5921.39	NR	5919.83	NR	Abandoned	NA	NA	NA
5886	5891.60	BBS	5891.70	.1	NA	NA	5891.77	.17	DRY	DRY	NA	NA	5891.28	BBS
6286	5875.8	CBD	5875.47	CBD	NA	NA	5875.68	CBD	NA	NA	5877.01	CBD	5877.03	CBD
6386	NA	NA	NA	NA	NA	NA	5888.44	2.6	5888.09	2.25	5887.75	1.91	5885.69	BBS
6486	5832.61	2.55	5833.77	3.71	NA	NA	5834.15	4.09	NA	NA	NA	NA	5830.82	.76
6886	5886.78	2.31	5887.07	2.6	NA	NA	5887.44	2.97	5886.88	2.41	NA	NA	5886.49	2.02
6986	5918.67	11.21	Abandoned		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
0187	5986.09	5.43	5984.16	3.5	NA	NA	5986.16	5.5	5984.48	3.82	NA	NA	5982.80	2.14
0487	5897.19	6.90	5897.23	6.91	5897.64	7.32	5901.81	11.49	5901.81	11.49	5901.76	11.44	5899.71	9.39
4387	5916.33	3.52	5916.52	3.71	5916.23	3.42	5918.51	5.7	5917.49	4.68	5917.74	4.93	5917.21	4.4
4487	DRY	DRY	DRY	DRY	DRY	DRY	5947.18	1.05	5945.79	BBS	DRY	DRY	NA	NA
4787	5875.19	BBS	DRY	DRY	5875.03	BBS	NA	NA	5879.21	3.7	5878.00	2.49	5877.28	1.77
4887	NA	NA	NA	NA	NA	NA	5906.33	6.71	5906.17	6.55	NA	NA	5905.61	5.99
4987	NA	NA	NA	NA	NA	NA	5909.41	1.5	5908.49	.58	NA	NA	5908.02	.11

*Elev. = Groundwater elevation above mean sea level (feet)
**Sat. = Saturated thickness above base of the screen
BBS = Denotes measured water level was below the bottom of the screen
CBD = Cannot be determined
NA = Denotes no measurement was reported
DRY = Denotes well was determined to be dry at the time of measurement
NR = No record of well construction or lithological information
1 = Groundwater elevations also presented in Figure 3-30, 3-32 and Table 3-9
Wells 7391 and 791 were drilled in Spring 1992

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Table 3-10

Upper Hydrostratigraphic Unit Water Levels January through July 1992 (Page 2 of 4)

Location	Groundwater Elevation and Saturated Thickness by Month[1]													
	January		February		March		April		May		June		July	
	*Elev.	**Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.
4987	NA	NA	NA	NA	NA	NA	5909.41	1.5	5908.49	.58	NA	NA	5908.02	.11
5087	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	DRY	DRY
5187	5949.71	.28	NA	NA	NA	NA	5949.75	.32	NA	NA	NA	NA	5949.72	.29
5287	5959.90	12.3	NA	NA	NA	NA	5960.05	12.45	NA	NA	NA	NA	5959.52	11.92
5387	5956.82	5.88	NA	NA	NA	NA	5956.45	5.5	NA	NA	NA	NA	5954.46	3.52
5487	5954.33	3.01	NA	NA	5954.90	3.58	5953.83	2.51	5951.70	.38	5955.04	3.72	5953.53	2.2
5587	NA	NA	DRY	DRY	5848.93	BBS	5851.99	BBS	5951.28	BBS	5850.05	BBS	5850.21	BBS
B301889	DRY	DRY	NA	NA	NA	NA	DRY	DRY	NA	NA	NA	NA	5842.73	BBS
B302089	5893.35	BBS	NA	NA	5893.19	BBS	5893.55	BBS	NA	NA	5895.01	1.01	5893.44	BBS
7391	NA	NA	NA	NA	5945.36	7.72	5945.55	7.91	5943.26	5.62	NA	NA	5942.44	4.8
791	NA	NA	NA	NA	NA	NA	NA	NA	Dry	Dry	Dry	Dry	Dry	Dry
30991	NA	NA	NA	NA	5838.48	.06	5842.97	3.55	5841.53	2.11	NA	NA	5841.53	2.11
31491	NA	NA	NA	NA	NA	NA	5888.98	5.3	5886.05	2.37	NA	NA	5884.73	1.05
31791	5863.89	BBS	5870.57	5.31	5870.72	5.46	5873.60	8.34	5870.6	5.34	NA	NA	5869.4	4.14
31891	5901.13	2.81	5901.1	2.77	5901.06	2.74	5903.38	5.06	5902.79	4.47	5902.86	4.54	5902.56	4.24

*Elev. = Groundwater elevation above mean sea level (feet)
**Sat. = Saturated thickness above base of the screen
BBS = Denotes measured water level was below the bottom of the screen
CBD = Cannot be determined
NA = Denotes no measurement was reported
DRY = Denotes well was determined to be dry at the time of measurement
NR = No record of well construction or lithological information
1 = Groundwater elevations also presented in Figure 3-30, 3-32 and Table 3-9
Wells 7391 and 791 were drilled in Spring 1992

Table 3-10

Upper Hydrostratigraphic Unit Water Levels January through July 1992 (Page 3 of 4)

Location	January *Elev.	January **Sat.	February Elev.	February Sat.	March Elev.	March Sat.	April Elev.	April Sat.	May Elev.	May Sat.	June Elev.	June Sat.	July Elev.	July Sat.
	Groundwater Elevation and Saturated Thickness by Month[1]													
33491	NA	NA	NA	NA	5917.27	BBS	5917.83	.46	5918.17	.8	5918.44	1.07	5917.67	.3
33691	NA	NA	5916.49	BBS	5917.00	BBS	5918.31	BBS	5918.68	BBS	5918.89	.01	NA	NA
33891	NA	NA	NA	NA	NA	NA	5918.56	BBS	5919.31	.47	5919.76	0.92	5919.18	.34
34591	NA	NA	5941.31	BBS	5941.68	BBS	5941.83	BBS	5941.94	BBS	5940.94	BBS	NA	NA
34791	5948.64	5.25	5948.66	5.27	5948.15	4.76	5951.99	8.60	5949.81	6.42	NA	NA	5948.98	5.59
35391	5950.68	BBS	5952.26	BBS	5950.29	BBS	5951.94	BBS	5952.39	BBS	5952.60	.18	5950.61	BBS
35691	5929.31	17.11	5926.50	14.29	5925.05	12.85	5925.33	13.13	5925.24	13.04	NA	NA	5924.91	12.71
35991	5957.37	BBS	5957.53	BBS	5957.88	BBS	5958.42	BBS	5958.68	BBS	5958.91	BBS	NA	NA
36191	5953.34	5.05	5957.77	9.48	5950.75	2.46	5959.45	11.16	5960.56	12.27	5959.97	11.68	5951.30	3.01
36391	5935.33	BBS	5937.31	.15	5937.95	.79	5944.47	7.31	5941.82	4.66	5944.92	7.76	5943.97	6.81
36691	5923.57	BBS	5924.82	0.89	5923.94	.01	5924.84	.91	5926.27	2.34	NA	NA	5926.56	2.63
36991	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
37191	5938.27	13.43	5938.12	13.28	5938.47	13.63	5942.68	17.84	5941.65	16.81	5940.21	15.37	5939.99	15.15
37591	5983.04	4.22	5984.18	5.36	5981.38	2.56	5987.72	8.9	5986.49	7.67	5986.37	7.55	5985.81	6.99
37691	NA	NA	NA	NA	NA	NA	5971.96	4.0	5968.24	.28	5968.34	.38	5967.61	BBS

*Elev. = Groundwater elevation above mean sea level (feet)
**Sat. = Saturated thickness above base of the screen
BBS = Denotes measured water level was below the bottom of the screen
CBD = Cannot be determined
NA = Denotes no measurement was reported
DRY = Denotes well was determined to be dry at the time of measurement
NR = No record of well construction or lithological information
1 = Groundwater elevations also presented in Figure 3-30, 3-32 and Table 3-9
Wells 7391 and 791 were drilled in Spring 1992

Table 3-10

Upper Hydrostratigraphic Unit Water Levels January through July 1992 (Page 4 of 4)

Location	January		February		March		April		May		June		July	
	Groundwater Elevation and Saturated Thickness by Month[1]													
	*Elev.	**Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.
37791	5982.6	1.04	NA	NA	5983.82	2.26	5984.72	3.16	NA	NA	NA	NA	5985.11	3.55
38191	5916.11	6.6	NA	NA	5916.57	7.1	5918.72	9.25	5918.20	8.73	NA	NA	5917.18	7.71
38291	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
38591	5858.07	1.01	5858.24	1.18	5858.27	1.21	5858.88	1.82	5858.23	1.17	NA	NA	5857.73	.67
38891	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
38991	5866.58	CBD	NA	NA	5875.61	CBD	5884.02	CBD	5883.89	CBD	NA	NA	5881.79	.52
39691	5998.27	1.01	5998.19	.93	5998.07	.81	6000.12	2.86	5998.88	1.62	NA	NA	5997.78	.52

*Elev. = Groundwater elevation above mean sea level (feet)
**Sat. = Saturated thickness above base of the screen
BBS = Denotes measured water level was below the bottom of the screen
CBD = Cannot be determined
NA = Denotes no measurement was reported
DRY = Denotes well was determined to be dry at the time of measurement
NR = No record of well construction or lithological information
1 = Groundwater elevations also presented in Figure 3-30, 3-32 and Table 3-9
Wells 7391 and 791 were drilled in Spring 1992

Table 3-11

Lower Hydrostratigraphic Unit Geotechnical Results - Phase III RFI/RI (Page 1 of 1)

Borehole Number/ Sample Number	Test Interval (feet below ground surface)	Grain Size (%) Sand	Silt	Clay	Lithologic Name	Atterberg Limits Liquid Limit/Plastic Limit/Plastic Index	Moisture Content (% dry wt)	Dry Density (lb/ft^3)	Wet Density (lb/ft^3)	Back-Pressure Permeability (cm/sec)[1]	Specific Gravity
37891/BH00747EBU1	45.70-46.15	08	64	28	Sandy clayey siltstone	38.3/19.9/18.4	--	--	--	--	3.72
37891/BH00746EBU1	46.15-46.40	--	--	--	--	--	14.8	100.3	115.2	5.0×10^{-8}	--
37991/BH00734EBU1	46.70-48.00	14	50	36	Sandy clayey siltstone	40.3/16.9/23.4	--	--	--	--	2.69
37991/BH00732EB41	46.45-46.70	--	--	--	--	--	15.1	92.0	105.9	7.8×10^{-5}	--
39191/BH00775EBU1	42.00-42.25	04	57	39	Clayey siltstone	43.2/17.4/25.8	--	--	--	--	2.76
39191/BH00774EBU1	42.25-42.50	--	--	--	--	--	15.6	109.8	126.9	1.6×10^{-6}	--

cm/sec = Centimeters per second
lb/ft^3 = Pounds per cubic foot
-- = Not analyzed
[1] Values of back-pressure permeability are also presented in Table 3-4.

Table 3-12

Vertical Distribution of Back-Pressure Permeability in Samples from Upper and Lower Hydrostratigraphic Units (Page 1 of 1)

Borehole Number	HSU	Lithological Classification	Sample Depth (feet below ground surface)	Back-Pressure Permeability (cm/sec)[1]
37891	Upper	Colluvium	1.10-1.35	1.8×10^{-7}
	Upper	Weathered claystone	7.50-7.75	3.8×10^{-8}
	Upper	Weathered claystone	10.20-10.45	4.7×10^{-8}
	Lower	Weathered claystone	46.15-46.40	5.0×10^{-8}
37991	Upper	Colluvium	3.50-3.75	1.3×10^{-8}
	Upper	Weathered claystone	11.40-11.65	5.5×10^{-9}
	Lower	Weathered siltstone	46.70-48.00	7.8×10^{-5}
38991	Upper	Colluvium	1.75-2.00	1.7×10^{-5}
	Upper	Colluvium	11.75-12.00	5.1×10^{-8}
	Upper	Weathered claystone	21.15-21.40	4.2×10^{-9}
39191	Upper	Colluvium	3.25-3.50	2.1×10^{-8}
	Upper	Weathered claystone	11.75-12.00	9.5×10^{-8}
	Upper	Weathered claystone	21.15-21.40	4.2×10^{-9}
	Lower	Weathered siltstone	42.25-42.50	1.6×10^{-6}

HSU = Hydrostratigraphic Unit
cm/sec = centimeters per second
1 Back-pressure permeability values are also presented on Tables 3-4 and 3-11.

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Table 3-13

Lower Hydrostratigraphic Unit Hydraulic Conductivity Estimates - Phase I and II RI (Page 1 of 2)

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lower HSU Classification
0387 BR	$1x10^{-8}$	Packer	62.9-72.6	Unweathered claystone
	$3x10^{-7}$	Packer	62.9-72.6	Unweathered claystone
	$2x10^{-8}$	Packer	62.9-72.6	Unweathered claystone
	$5x10^{-8}$	Packer	74.6-84.2	Unweathered claystone
	$4x10^{-8}$	Packer	74.6-84.2	Unweathered claystone
	$5x10^{-8}$	Packer	88.2-97.9	Unweathered claystone
	$2x10^{-7}$	Packer	N/A	Sandstone
	$3x10^{-6}$	Drawdown/recovery	102.8-107.8	Sandstone and claystone
0587 BR	$1x10^{-6}$	Packer	36.1-45.7	Weathered claystone
	$2x10^{-7}$	Packer	36.1-45.7	Weathered claystone
	$1x10^{-6}$	Packer	N/A	Sandstone
	$7x10^{-5}$	Drawdown/recovery	42.0-51.2	Sandstone and claystone
	$7x10^{-5}$	Slug	42.0-51.2	Sandstone and claystone
0887 BR	$7x10^{-7}$	Packer	62.6-72.3	Weathered claystone
	$9x10^{-8}$	Packer	83.5-93.1	Unweathered claystone with lignite
	$1x10^{-8}$	Packer	83.5-93.1	Unweathered claystone with lignite
	$1x10^{-7}$	Packer	N/A	Unweathered claystone with lignite

HSU = Hydrostratigraphic Unit
N/A = Data not available
[1]Hydraulic conductivity values are also presented in Figure 3-42

Table 3-13

Lower Hydrostratigraphic Unit Hydraulic Conductivity Estimates - Phase I and II RI (Page 2 of 2)

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lower HSU Classification
0887 BR	$3x10^{-6}$	Drawdown/recovery	84.0-89.0	Unweathered claystone with lignite
4587 BR	$2x10^{-7}$	Packer	60.6-70.2	Unweathered claystone
	$3x10^{-7}$	Packer	60.6-70.2	Unweathered claystone
	$2x10^{-8}$	Packer	70.2-79.2	Unweathered claystone
	$9x10^{-7}$	Packer	70.2-79.2	Unweathered claystone

(Source: Rockwell 1988)

HSU = Hydrostratigraphic Unit
N/A = Data not available
[1]Hydraulic conductivity values are also presented in Figure 3-42

Table 3-14

Lower Hydrostratigraphic Unit Hydraulic Conductivity Estimates - Phase III RFI/RI (Page 1 of 1)

Well/ Piezometer Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithologic Description	Lower HSU Classification
37891	$5x10^{-7}$ $1x10^{-6}$	Slug injection/ slug withdrawal	43.4-53.0	Silty claystone, clayey siltstone	Weathered claystone, siltstone
37991	$7x10^{-6}$	Bail down/recovery	45.4-55.0	Claystone, sandy, clayey siltstone	Weathered claystone, siltstone
39191	$2x10^{-5}$	Bail down/recovery	33.0-42.6	Clayey siltstone, silty claystone	Weathered claystone, siltstone
39291	$3x10^{-5}$ $3x10^{-5}$	Slug injection/ slug withdrawal	34.2-43.8	Claystone, silty claystone, clayey siltstone	Weathered claystone, siltstone

Results could not be obtained from Packer Tests attempted @ 37891, 37991 and 39291.
cm/sec = centimeters per second
[1] Hydraulic conductivity values are also presented in Figure 3-42.

Table 3-15

Lower Hydrostratigraphic Unit Water Levels (January 1992) (Page 1 of 1)

Well/Piezometer	Top of Casing (feet above MSL)	Bottom of Screen (feet above MSL)	Water Level (feet below top of casing)	Groundwater Elevation January 1992 (feet above MSL)[1]
0587	5930.16	5876.51	46.62	5883.54
0887	5921.55	5830.68	NR	NR
4587	5950.91	5848.27	89.60	5861.31
37891	5926.29	5872.02	42.71	5883.58
37991	5933.55	5876.25	49.42	5884.13
39191	5918.32	5875.36	37.92	5880.40
39291	5910.21	5864.43	32.24	5877.97

MSL - Mean Sea Level
NR - No record
[1] Groundwater elevations are presented in Figure 3-43.

Table 3-16

Upper Hydrostratigraphic Unit Average Linear Groundwater Flow Velocities. (Page 1 of 1)

Location	Lithological Unit	Average Hydraulic Gradient i (feet/foot)	Average Hydraulic Conductivity K (feet/min)	Estimated Effective n (percent)	Average Linear Velocity V_{ave} (feet/yr)†
Western portion of site south of 881 Building	Colluvium and disturbed colluvium	0.10	* $1.5x10^{-5}$	10	7.8
IHSS 119.1	Colluvium	0.14	** $9.4x10^{-5}$	10	69
Along western Woman Creek	Woman Creek valley fill alluvium	.026	*** $1.3x10^{-3}$	10	178

* K = geometric mean of hydraulic conductivity values at wells 35691, 36191, and 6986(Tables 3-7, 3-6)
** K = geometric mean of hydraulic conductivity values at wells 38191 and 0487 (Tables 3-6, 3-7)
*** K = geometric mean of hydraulic conductivity values at wells 6886 and 38591 (Tables 3-6, 3-7)
† V_{ave} (feet/min) x 5.26 x 10^5 (min/year) = V_{ave} (feet/yr)

Average hydraulic gradient (i) = measured from water table map (Figure 3-30) along flow paths
Average hydraulic conductivity (K) = geometric mean of values in nearby tested wells
Effective porosity (n) = 10% estimated
Average velocity (V_{ave}) = after (Fetter 1988): $V_{ave} = Ki/n$
where: K = hydraulic conductivity
i = hydraulic gradient
n = effective porosity

Note: Results of tracer tests are not included in this table.

Table 3-17

Upper Hydrostratigraphic Unit Volumetric Calculations for January 1992, April 1992 (Page 1 of 1)

		Saturated Map Area (acres)	Saturated Thickness (feet)	Volume of Saturated Materials (acre-feet)	Effective Porosity	Volume of Groundwater Available for Movement or Yield (acre-feet)
Area within OU1 boundaries	January	14.66	4	58.35	0.1	5.8
	April	17.21	3	51.63		5
Area with OU1 and downgradient North of Woman Creek	January	20	2	40	0.1	4.0
	April	28.6	2	60		6.0

HSU = Hydrostratigraphic unit
OU1 = Operable Unit No. 1

Note: Total map area with OU1 boundaries equals 18.7 acres (from Figure 3-30).
Saturated map area was calculated using planimetric methods.
Saturated thickness is typical value (from Figure 3-29).
Effective porosity range is based on horizontal effective porosity values presented for average ground water flow velocity calculations. (Table 3-16)

Table 3-18

Vertical Hydraulic Gradients Between the Upper and Lower Hydrostratigraphic Unit (Page 1 of 1)

Well/ Piezometer	Lithologic Unit	Water Level Elevation January 1992 (feet above sea level)[1]	*Screen Midpoint Elevation (feet above sea level)	**Estimated Vertical Hydraulic Gradient i_v (feet/foot)
0487	Colluvium	5890.32	5893.76	1.06
39291	Bedrock	5864.43	5869.43	
4387	Colluvium	5916.33	5914.57	0.87
37891	Weathered bedrock	5883.58	5877.02	
38191	Colluvium	5916.11	5911.97	1.05
39191	Weathered bedrock	5880.40	5877.86	
4387	Colluvium	5916.33	5914.57	0.98
39191	Weathered bedrock	5880.40	5877.86	
				Geometric mean = 0.98

* = Calculated as mid-point of saturated screen interval (see Appendix)

** = $i_v = \dfrac{\text{Water level in bedrock well — water level in colluvial well}}{\text{midpoint of bedrock well screen — midpoint of colluvial well screen}}$

[1]Goundwater elevations are also presented in Tables 3-9 and 3-15.

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Table 3-19

Vertical Average Linear Groundwater Velocity Between the Upper and Lower Hydrostratigraphic Unit Near IHSS 119.1 (Page 1 of 1)

Location	Average Hydraulic Gradient i (feet/foot)	Average Hydraulic Conductivity K (feet/minute)	Effective Porosity n (%)	Linear Average Velocity V_{ave} (feet/year)
IHSS 119.1	.98	3.3×10^{-8}	10	.17

Average hydraulic gradient (i) = geometric mean of values presented in Table 3-18
Average hydraulic conductivity (K) = geometric mean of values for nearby tested wells (37891, 37991, 38991, 39191) (using values in upper HSU bedrock Table 3-4)
Effective porosity (n) = 10%
Average velocity (V_{ave}) = after (Fetter 1988): $V_{ave} = Ki/n$

where: K = hydraulic conductivity
i = hydraulic gradient
n = effective porosity

and:
V_{ave} (feet/minute) x 5.26×10^{-5} (minute/year) = V_{ave} (feet/year)

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Table 3-20

Water Levels in Colluvial and Shallow Bedrock Wells Near the French Drain

				Groundwater Elevation 1993			
Well ID	Ground Surface (feet above MSL)	Top of Casing (feet above MSL)	Base of Screen (feet above MSL)	Jan. 20	Feb. 25	Mar. 26	April 02
10092	5898.4	5900.47	5879.6	Dry	5877.35[a]	5877.5216[a]	5877.5[a]
10192	5922.7	5924.3	5905.9	Dry	Dry	Dry	Dry
10292	5923.8	5925.46	5901.1	Dry	Dry	Dry	Dry
10392	5930.2	5932.05	5905.0	Dry	Dry	Dry	Dry
10492	5930.8	5932.81	5900.47	5902.7	5902.58	5902.47	5902.53
10592	5936.1	5937.93	5912.1	Dry	5913.87	5913.62	Dry
10692	5941.5	5943.6	5922.1	5938.07	5938.09	5938.5	5939.07
10792	5915.02	5917.1	5892.61	5894.02	5893.7	5893.52	5893.78
10892	5928.1	5929.2	5904.71	Dry	Dry	Dry	Dry
10992	5896.9	5898.56	5867.5	5866.79[a]	5866.75[a]	5866.41[a]	Dry
11092	5893.3	5895.31	5874.3	5873.00[a]	5872.91[a]	5872.68[a]	5872.74[a]
31491	5902.6	5905.03	5883.68	5881.92[a]	NA*	5881.98[a]	5881.55[a]
31891*	5916.9	5919.52	5898.32	5901.98	NA*	5901.47	5902.47
38891	5891.3	5893.24	5881.96	Dry	Dry	Dry	Dry
4787	5882.8	5884.64	5875.51	5875.27[a]	5875.42[a]	5875.43[a]	5875.59[a]
39991	5929.9	5932.36	5911.7	5909.19	D	D	D
45391	5891.2	5894.24	5873.5	5883.67	NA	5868.92[a]	Dry

[a] = Below base of screen
NA* = Was not obtained
D = Well was damaged and was abandoned in June 1993
* = Represents subcropping sandstones

Table 3-21

Upper Hydrostratigraphic Unit Water Levels (April 1993)

Location	Bottom of Screen (feet above MSL)	Contact Elevation (feet above MSL)	Top of Casing (feet above MSL)	Water Level Below Top of Casing	Ground Water Elevation (feet above MSL)
5886	5891.71	5892.21	5897.65	5.76	5891.89
6286	5866.81	5875.54	5903.18	28.2	5874.98
6386	5885.84	5886.29	5902.01	16.58	BBS
6486	5830.06	5830.56	5841.05	6.9	5834.15
6886	5884.47	5885.17	5890.49	3.09	5887.4
0187	5980.66	5980.62	5994.08	12.09	5981.99
0487	5890.32	5890.29	5911.58	10.10	5901.48
4387	5912.81	5913.06	5926.41	9.23	5917.18
4487	5946.13	5946.43	5951.10	DRY	DRY
4787	5875.51	5873.76	5884.64	9.05	BBS
4887	5899.62	5899.67	5911.41	6.15	5905.26
4987	5907.91	5903.66	5914.27	4.12	5910.15
5087	5919.64	5920.64	5934.78	DRY	DRY
5187	5949.43	5950.77	5965.22	15.55	5949.67
5287	5947.60	5947.85	5969.57	9.27	5960.3
5387	5950.94	5949.99	5961.81	DRY	DRY
5487	5951.32	5951.85	5957.62	2.79	5954.83
5587	5852.74	5852.89	5858.39	9.36	BBS
B301889	5844.20	5844.50	5868.83	DRY	DRY

Table 3-21 (Continued)

Upper Hydrostratigraphic Unit Water Levels (April 1993)

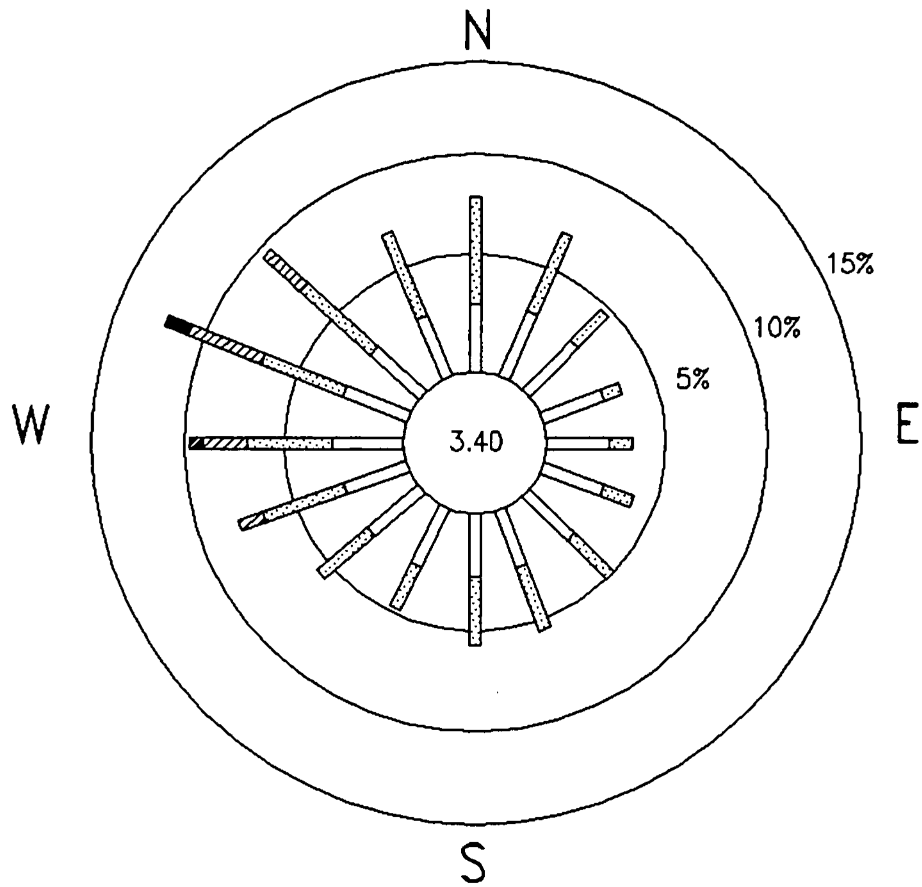
Location	Bottom of Screen (feet above MSL)	Contact Elevation (feet above MSL)	Top of Casing (feet above MSL)	Water Level Below Top of Casing	Ground Water Elevation (feet above MSL)
B302089	5894.2	5894	5909.55	16.44	BBS
7391	5937.64	5941.04	5950.61	8.67	5942
791	5888.61	5889.51	5908.27	21.3	BBS
30991	5839.42	5840.32	5851.82	8.72	5843.1
31491	5883.68	5886.08	5905.03	23.48	BBS
31891	5898.32	5999.7	5919.52	17.05	5902.47
31791	5865.26	5868.26	5879.80	7.83	5871.97
32591	5898.36	5898.96	5917.41	18.7	5898.71
33491	5917.37	5918.01	5928.59	11.12	5917.47
33691	5918.88	5919.19	5929.24	10.72	BBS
33891	5918.84	5919.44	5929.94	12.14	BBS
34591	5943.29	5943.99	5954.63	13.61	BBS
34791	5943.39	5943.39	5953.91	3.15	5950.76
35391	5952.42	5954.00	5963.03	13.13	BBS
35691	5912.20	5913.56	5941.36	18.85	5922.51
35991	5959.55	5961.10	5976.45	18.03	BBS
36191	5948.29	5948.89	5965.17	12.91	5952.26
36391	5937.16	5938.17	5967.01	28.55	5938.46
36691	5923.93	5924.76	5951.52	24.88	5926.64

Table 3-21 (Continued)

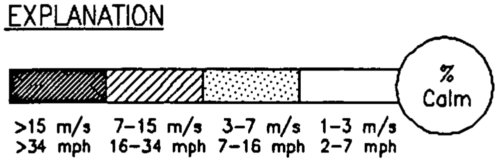
Upper Hydrostratigraphic Unit Water Levels (April 1993)

Location	Bottom of Screen (feet above MSL)	Contact Elevation (feet above MSL)	Top of Casing (feet above MSL)	Water Level Below Top of Casing	Ground Water Elevation (feet above MSL)
36991	5960.86	5961.48	5972.31	10.68	5961.63
37191	5924.84	5925.36	5948.29	10.05	5938.24
37591	5978.82	5979.42	5993.45	8.00	5985.45
37691	5967.96	5968.26	5985.24	20.47	BBS
37791	5981.56	5982.16	6004.18	20.63	5983.55
38191	5909.47	5909.82	5926.40	9.34	5917.37
38291	5915.79	5916.09	5926.71	10.42	5916.29
38591	5857.06	5857.47	5866.62	7.83	5858.79
38891	5881.96	5882.26	5893.24	DRY	DRY
38991	•5856.28	5873.58	5875.49	17.32	5878.17
39691	5997.26	5999.46	6008.37	10.64	5997.73

•	-	Saturated thickness presented is saturated interval above the screen.
NR	-	No record available.
MSL	-	Mean Seal Level.
0.00	-	Denotes well was determined to be dry at the time of measurement.
BBS	-	Denotes measured water level was below the bottom of the screen.
NA	-	Not available for measurement.
CBD	-	Cannot be determined.



EXPLANATION



See Table 3–1 for wind direction frequency by wind speed class

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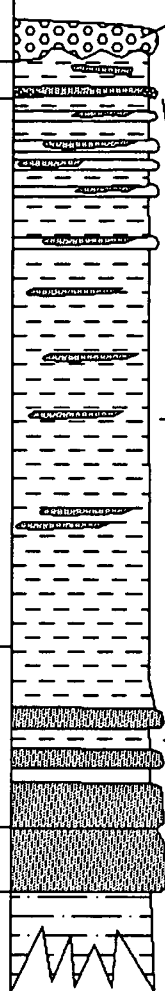
Annual Wind Rose
for the Rocky Flats Plant
1990 through 1991

Figure 3–3

OCTOBER 1993

R74292.MBT10493

AGE	FORMATION	THICKNESS (feet)
Quaternary	Rocky Flats Alluvium/ Colluvium	0–100
Cretaceous	Arapahoe Fm.	0–120
	Laramie Formation	600–800
		upper interval: 300–500
		lower interval: 300
	Fox Hills Sandstone	90–140
	Pierre Shale and older units	



After EG&G 1992

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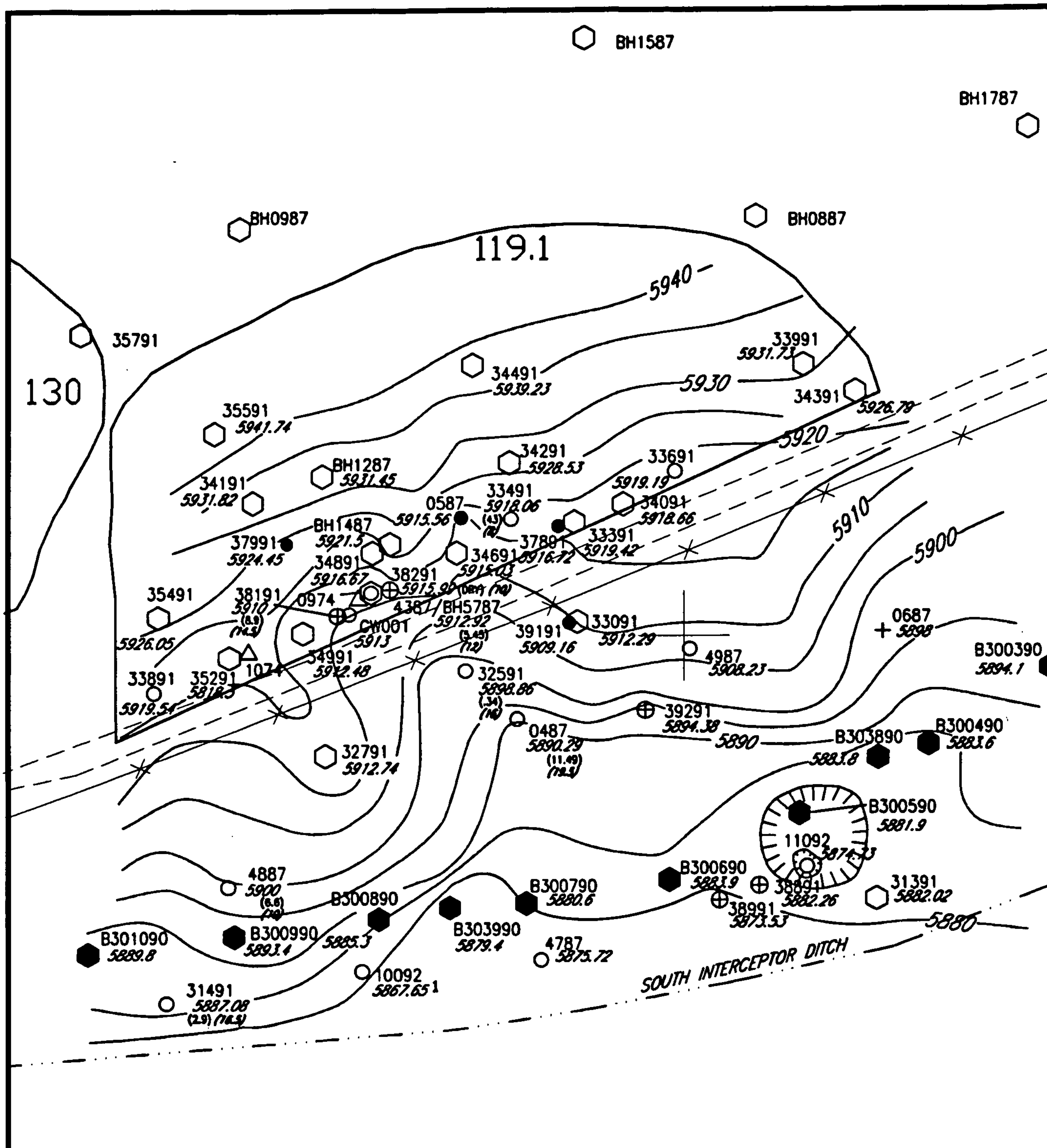
Generalized Stratigraphic Section for the Rocky Flats Plant

Figure 3–7

OCTOBER 1993



EXPLANATION

104	INDIVIDUAL HAZARDOUS SUBSTANCE
o B301889	ALLUVIAL WELL
• B304789	BEDROCK WELL
+ 1187A	ABANDONED WELL
△ 0271	PRE-1986 WELL
⬡ BH1587	BOREHOLE
⬢ B300390	FRENCH DRAIN BOREHOLES
⊕ 38991	PIEZOMETERS
5900	TOP OF BEDROCK PER EBASCO
(DRY)	SATURATED SECTION THICKNESS (4/92)
(12)	ALLUVIAL THICKNESS

5900 BEDROCK TOPOGRAPHY C.I. = 5'

[1] ANOMALOUS BEDROCK ELEVATIONS - NOT CONTOURED

-N-

0 50 100

SCALE: 1" = 100'

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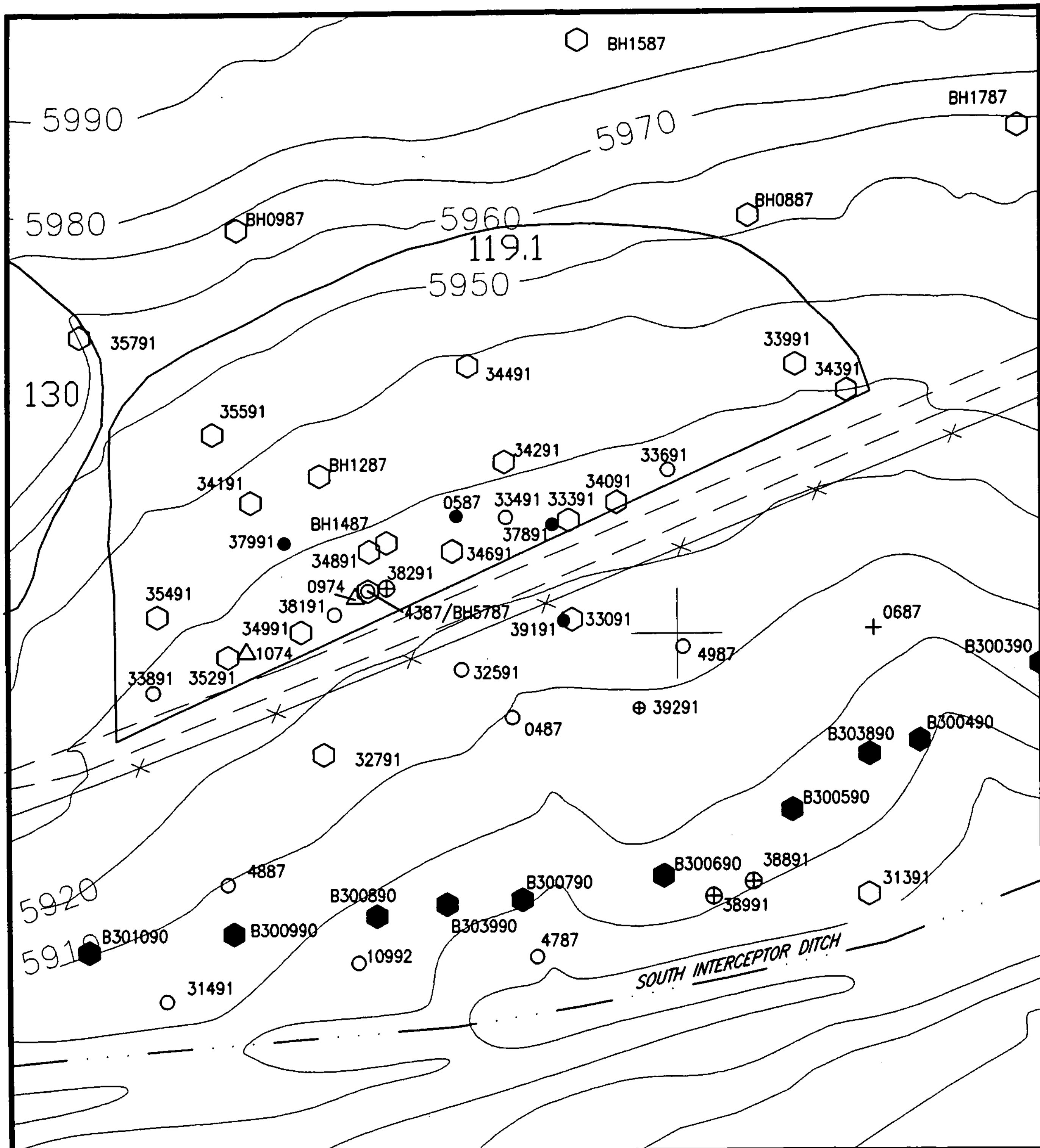
Bedrock Topography Near IHSS 119.1

Figure 3-24

FEBRUARY 1994

R74119.PJCW-051794/100



EXPLANATION

104 INDIVIDUAL HAZARDOUS SUBSTANCE

o B301889	ALLUVIAL WELL
• B304789	BEDROCK WELL
+ 1187A	ABANDONED WELL
△ 0271	PRE-1986 WELL
⬡ BH1587	BOREHOLE
⬢ B300390	FRENCH DRAIN BOREHOLES
⊕ 38991	PIEZOMETERS
	CONTOUR INTERVAL = 10 FEET

-N-

0 50 100

SCALE: 1"=100'

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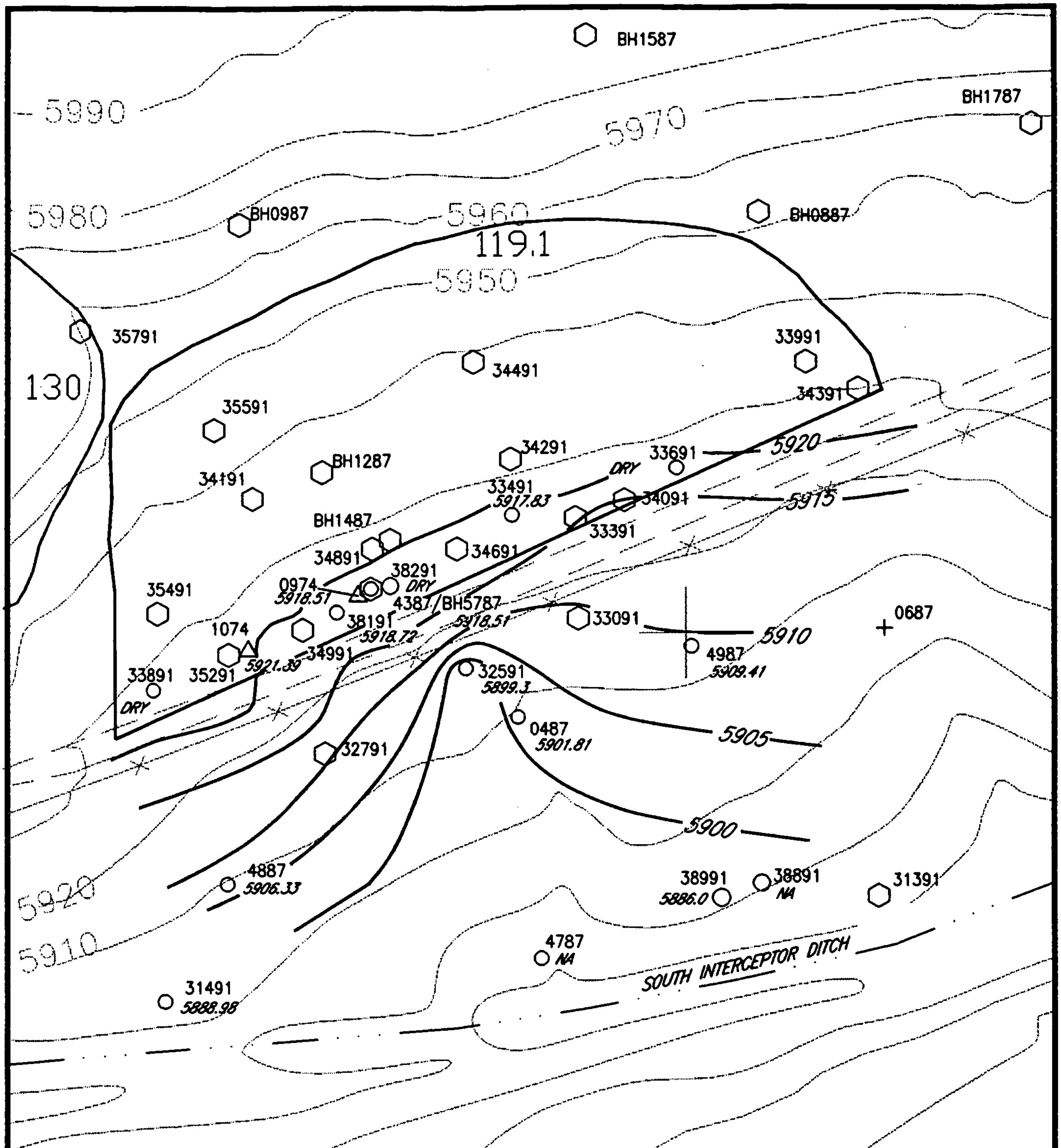
Topography
in the Vicinity of IHSS 119.1

Figure 3-25

AUGUST, 1993

R74118.PJ-082793/100



EXPLANATION

104 INDIVIDUAL HAZARDOUS SUBSTANCE

- o B301889 ALLUVIAL WELL
- • B304789 BEDROCK WELL
- + 1187A ABANDONED WELL
- Δ 0271 PRE-1986 WELL
- ⬡ BH1587 BOREHOLE
- FRENCH DRAIN BOREHOLES
- ○ PIEZOMETERS
- 5900 WATER LEVEL
- 5900 UPPER HYDROSTRATIGRAPHIC UNIT C.I. = 5'

NA = NOT AVAILABLE

-N-

0 50 100

SCALE: 1"=100'

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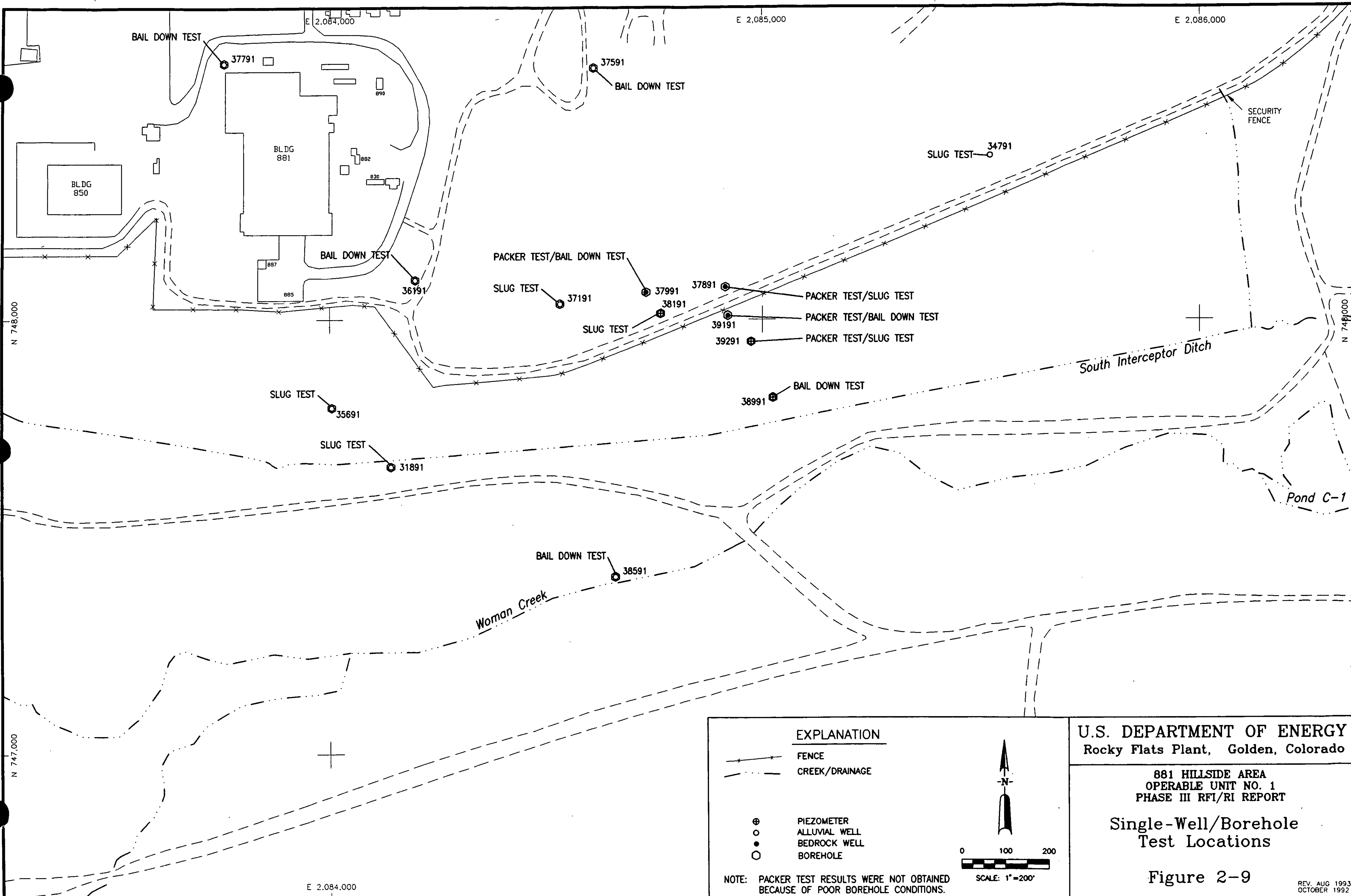
Upper Hydrostratigraphic Unit Water Levels Near IHSS 119.1 April 1992

Figure 3-33

OCTOBER 1993

R74120.PJMBpj-053194/100



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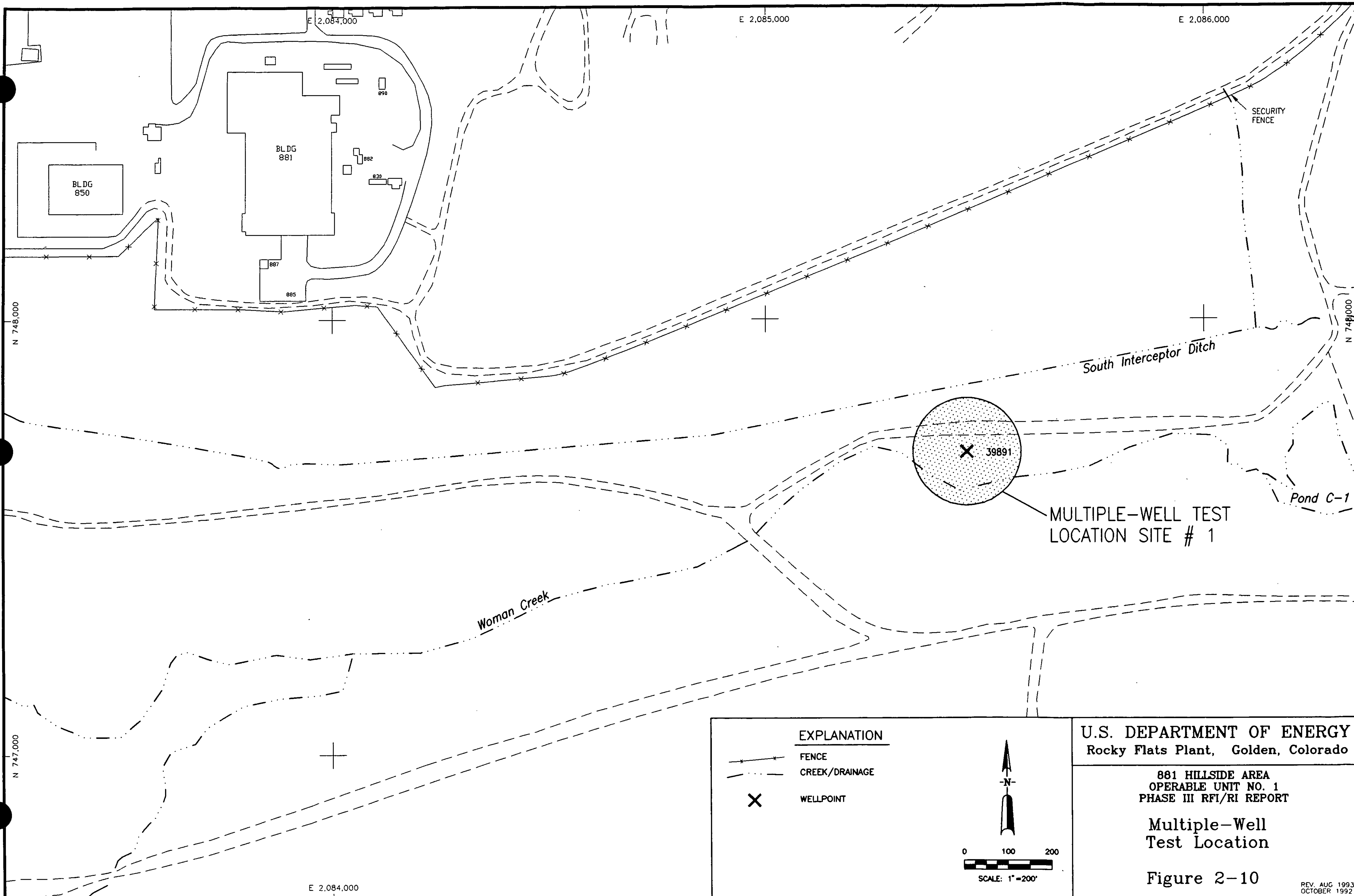
Single-Well/Borehole Test Locations

Figure 2-9

REV. AUG 1993
OCTOBER 1992

R74084.MBMB102693/200



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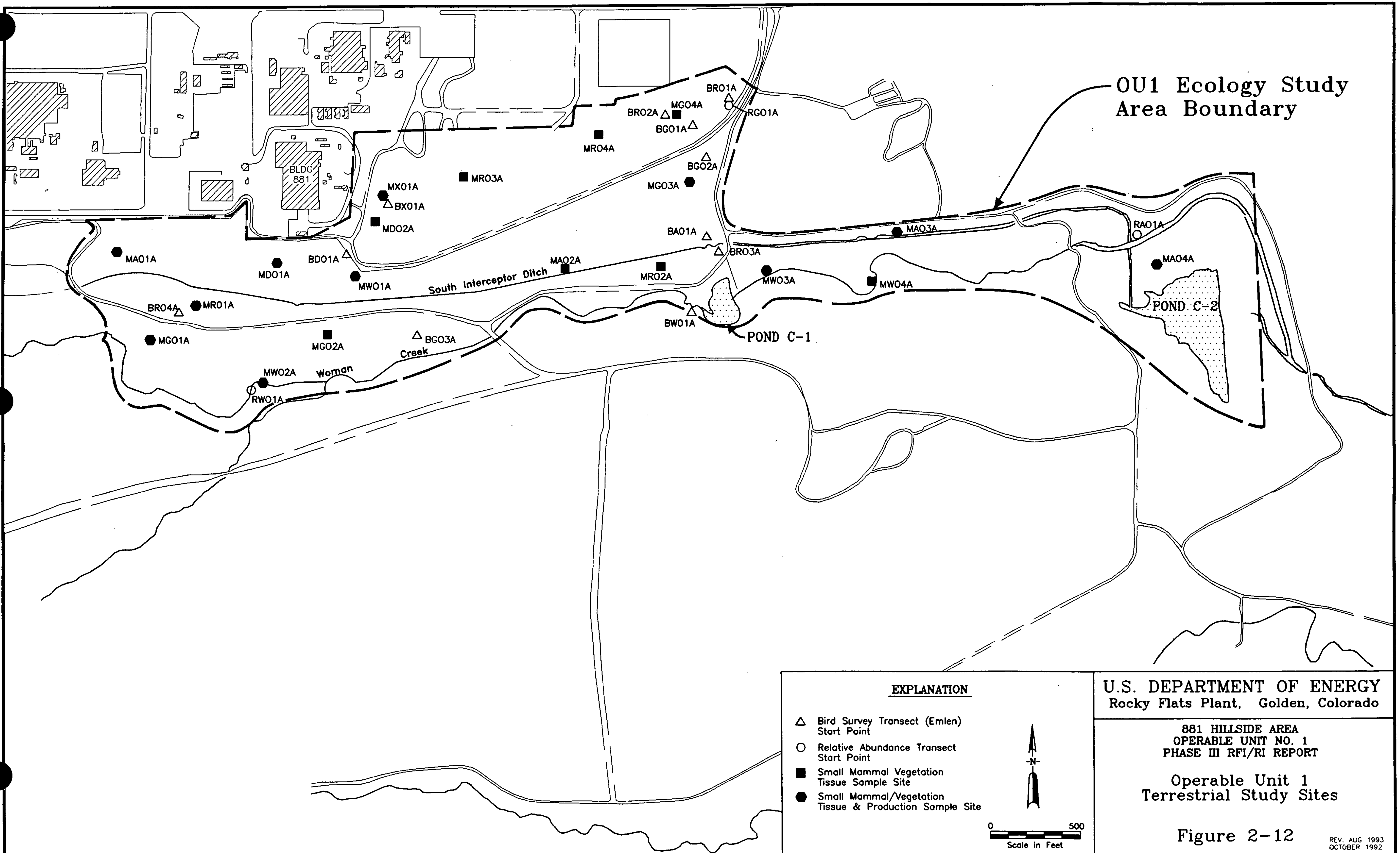
Multiple-Well
Test Location

Figure 2-10

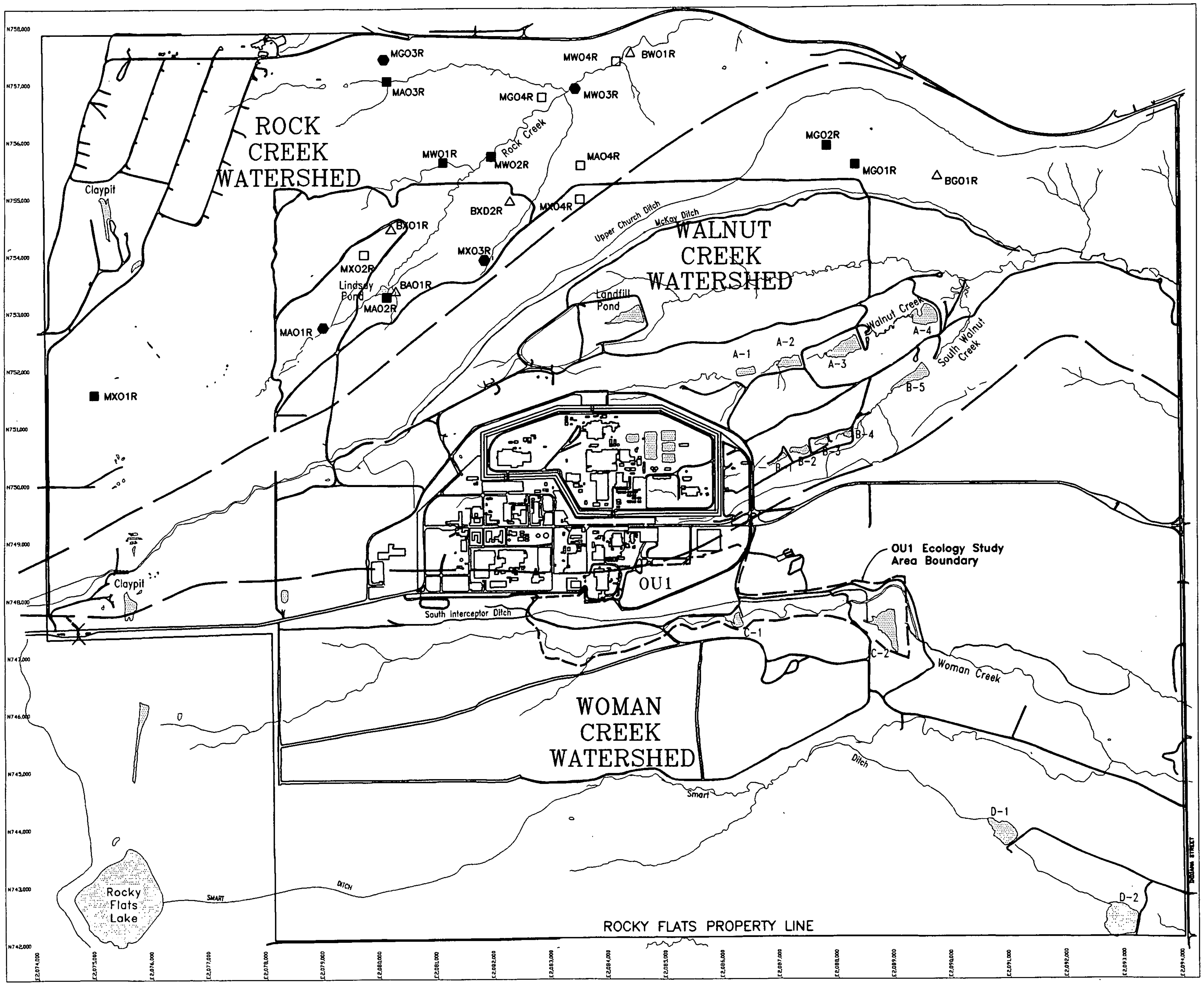
REV. AUG 1993
OCTOBER 1992

R74085.MBMB102693/200



Operable Unit 1
Terrestrial Study Sites

Figure 2-12



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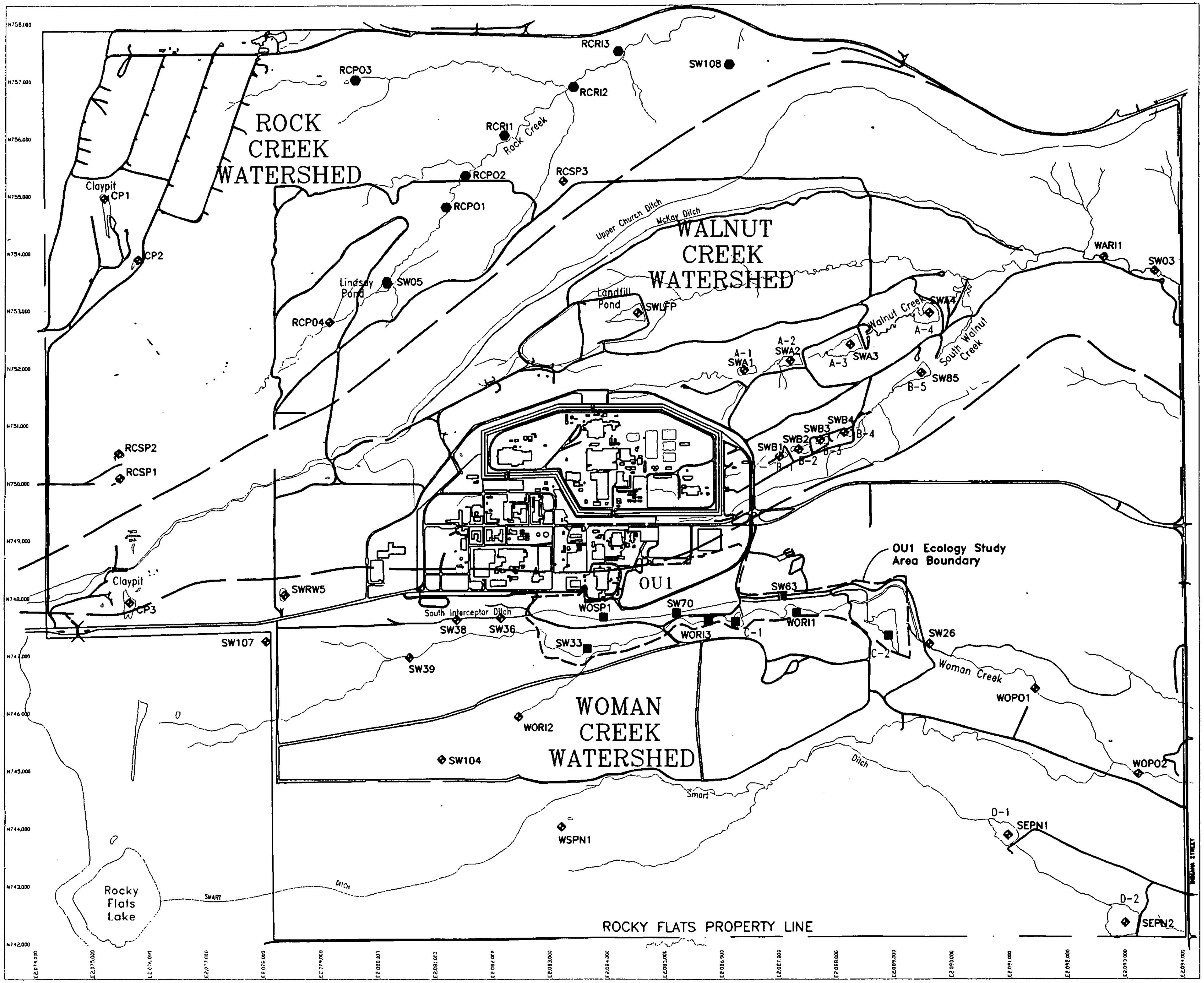
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Terrestrial Reference Sites

Figure 2-13

AUGUST 1993

R74263.MBMB102693/1800



LEGEND

Watershed Boundary

Open Water

■ OU1 Aquatic Study Sites

● OU1 Aquatic Reference Sites

◈ Other Sample Sites

0 305 610
Scale in Meters

0 1000 2000
Scale in Feet

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OPERABLE UNIT NO. 1
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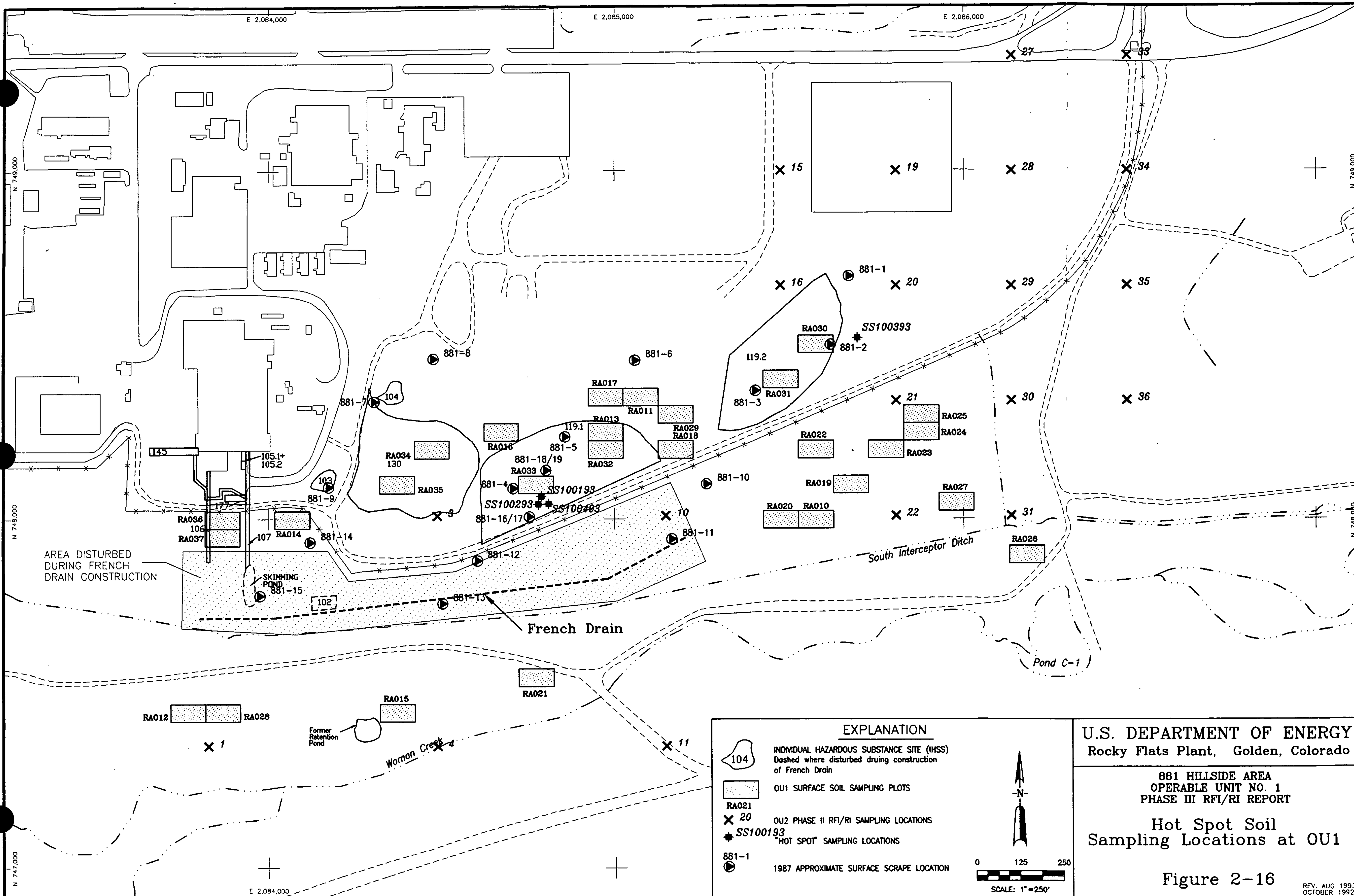
Aquatic Study Sites and Aquatic Reference Sites

Figure 2-14

REV. AUG. 1993
OCTOBER 1992

R74264 MB082593/1800



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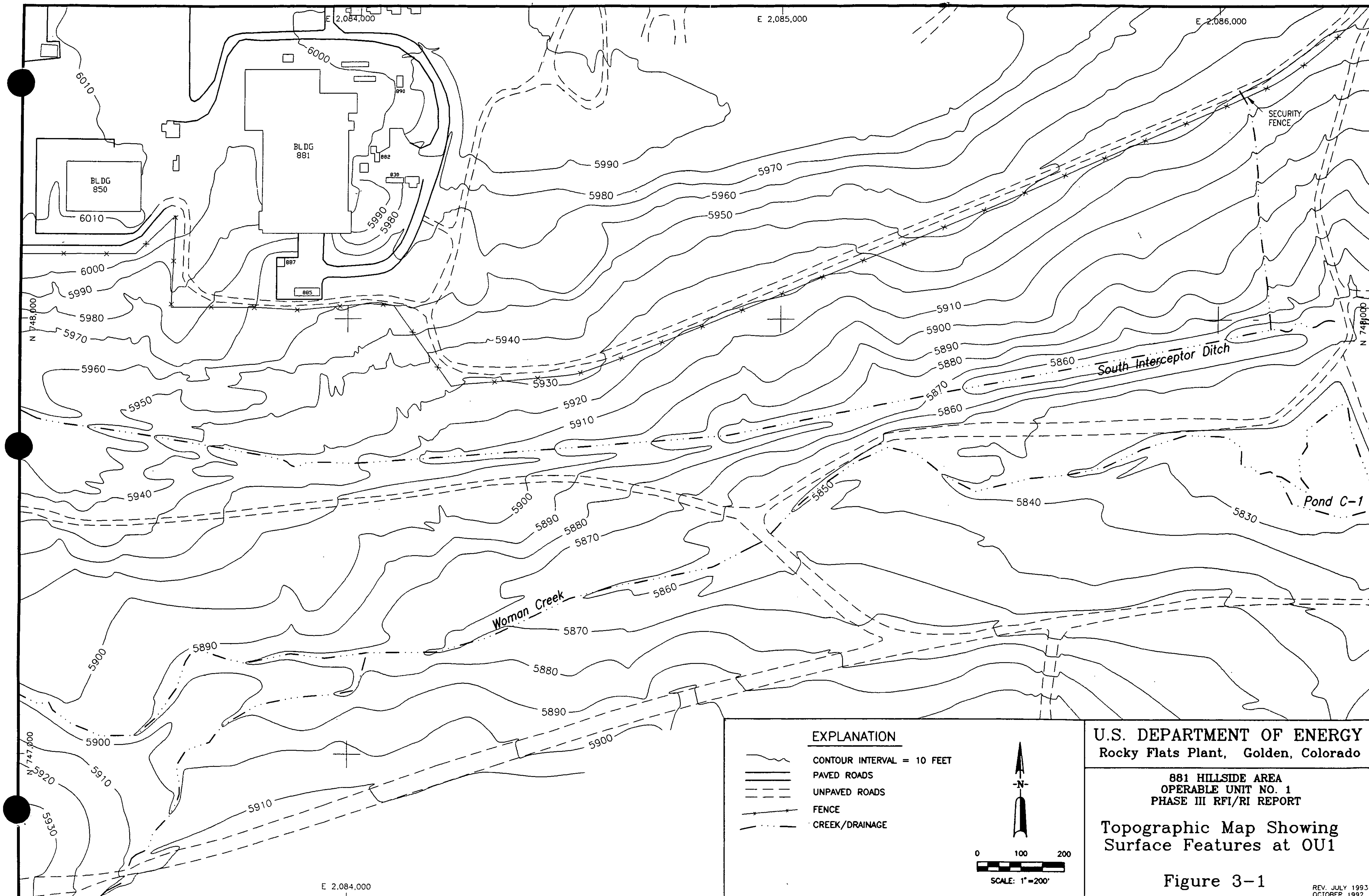
PHASE III RFI/RI REPORT

Hot Spot Soil Sampling Locations at OU1

Figure 2-16

REV. AUG 1993
OCTOBER 1992

R74063.PJMB102693/250



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881 HILLSIDE AREA
OPERABLE UNIT NO. 1
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Topographic Map Showing Surface Features at OU1

Figure 3-1

REV. JULY 1993
OCTOBER 1992

R74019.MB072193

North Plains Community Plan Study Area Summary Map

AREA	TYPE OF LAND USE
1	Cemetery
2.	Existing Parks and Recreation Areas, Schools
5	Open Space, Parks and Recreation Areas, Agriculture, Ranching, and Residential up to 1 du/10 ac
6	Residential up to 4 du/ac
7	Light Industrial
8	Retail and Office
9	Residential up to 4 du/ac
10	Business Park, i.e., Office, Light Industrial
11	Aviation Use, Jefferson County Airport, Business Park, i.e., Office, Light Industrial
12	Business Park, i.e., Office, Light Industrial
13	Residential up to 2 du/ac
14	Business Park, i.e., Office, Light Industrial
15	Business Park, i.e., Office, Light Industrial
16	Residential up to 2.5 du/ac
17	Residential up to 10 du/ac
18	Infill Area. Retail, Office, Light Industrial
19	Infill Area. Retail, Office and Light Industrial, Residential up to 15 du/ac
20	Infill Area. Recreational Vehicle Parks, Retail, Office, Light Industrial, Residential up to 15 du/ac
21	Mixed Use Area. A balance of Office, Light Industrial, Retail, Community Facilities, Residential
22	Office
23	Residential up to 2.5 du/ac outside existing Retail, Office and Industrial areas
24	Residential up to 3 du/ac
25	Residential up to 3.5 du/ac
26	Residential up to 2.5 du/ac
27	Residential up to 2 du/ac adjacent to Van Bibber floodplain
28	Residential up to 2.2 du/ac
29	Residential up to 2.7 du/ac
30	West 64th Avenue and McIntyre Street Activity Center. Residential up to 15 du/ac, Retail, Office, Light Industrial
31	Golf Course, Open Space and Residential up to 4 du/ac, neighborhood-scale Retail and Office development of approximately 100,000 square feet north of West 64th Avenue
32	Residential up to 1.5 du/ac
33	Residential up to 1 du/ac
34	Open Space, Conservation because Geologic Hazard Area exists
35	Residential 1 du/5 to 35 ac, Office and limited Retail, Research and Development, Open Space and Trails
36	Residential up to 4 du/ac, Neighborhood-scale Retail and Office development up to 150,000 square feet in one quadrant of the West 58th Avenue and Colorado State Highway 93 intersection
37	Activity Center. Residential up to 10 du/ac, Light Industrial, Office, Retail, and Tourist Services
38	Residential up to 2.5 du/ac
39	Residential 1 du/5 to 35 ac
40	Residential up to 4 du/ac, Retail and Office up to a 1500 foot radius of West 64th Avenue and W-470 interchange, west of Colorado State Highway 93
41	Office, Industrial
42	Special Use Area. Office and Industrial if hazards can be mitigated
43	Residential up to 1 du/2 ac
44	Mixed Use. Office, Light Industrial, Residential up to 4 du/ac
45	Office, Industrial
46	Special Use Area. Office, Industrial if hazards can be mitigated
47	Office, Light Industrial, Golf Course, and limited Residential up to 4 du/ac
48	Office, Industrial; Retail approximately 1500 feet around the W-470 and Indiana Street and W-470 and West 104th Avenue interchanges
49	Retail, Office
50	Equestrian center, Residential 1 du/2 ac
51	Mixed Use Area. Residential up to 1 du/2 ac, Office, Light Industrial
52	Special Use Area. Rocky Flats Nuclear Facility and buffer zone

Enclaves: Residential up to 4 du/ac or existing zoning, whichever is greater. If adjacent land use is non-residential, then a similar land use could be considered provided adverse impacts are mitigated

NOTES: du/ac: dwelling units per acre

Ranching and Agriculture land uses, if consistent with current zoning, are permitted anywhere in the North Plains.

Ancillary retail is allowed in all office/industrial areas unless explicitly precluded.

Refer to specific Subarea policies for conditions affecting development in areas shown on the Summary Map and legend. In addition, the General Policies Section of this plan applies.

N

Nonresidential: Retail, or Office, or Industrial

Mixed Use: Residential & Retail, or Office, or Industrial

Open Space & Rural Residential 1 du/5 to 35 acres

Residential up to 4 du/ac

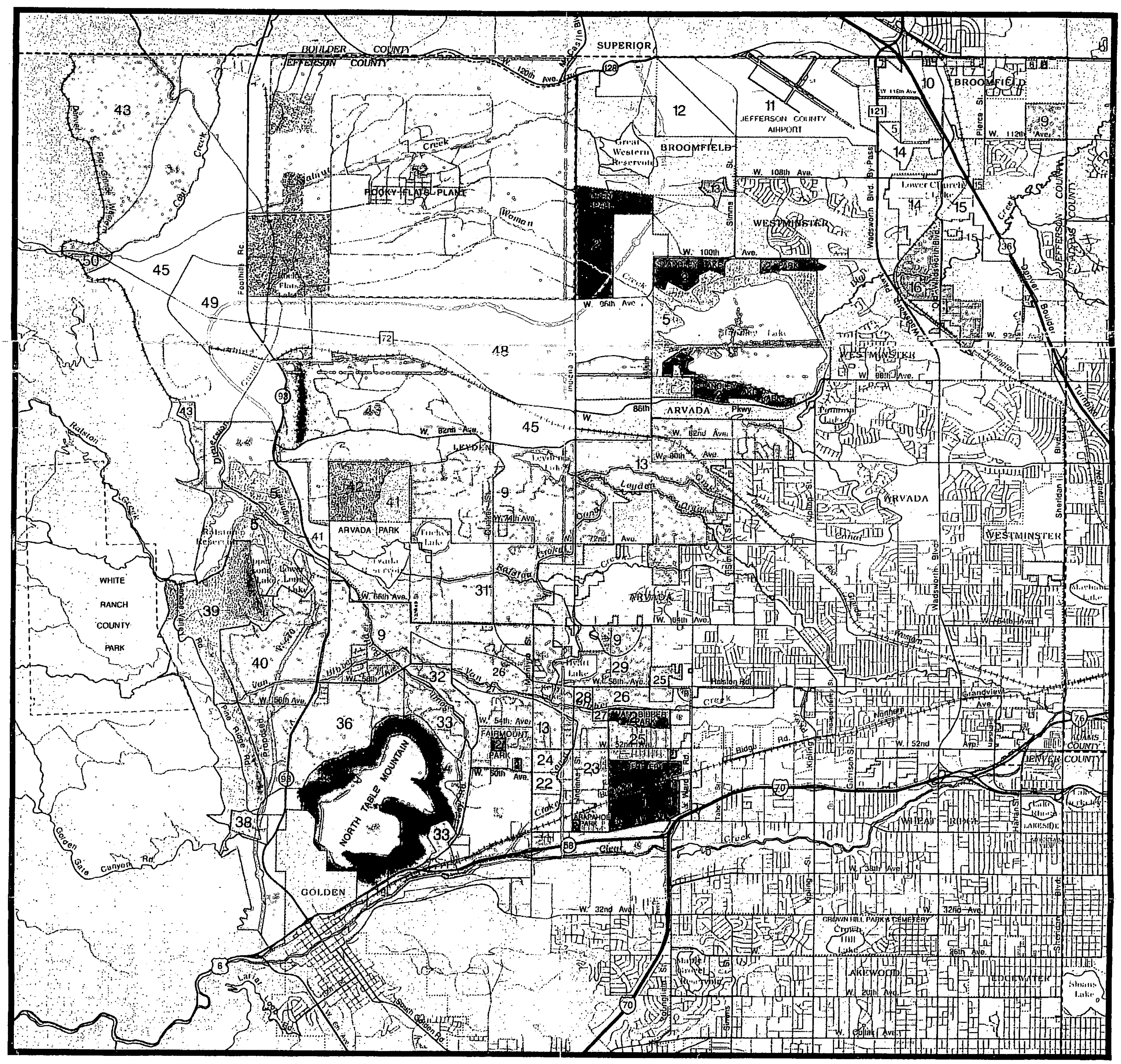
Open Space, Parks & Recreation Areas, Schools, & Cemetery

Special Use

Enclaves

Sanitary Landfills

Zoned for Mining



-N-

1 MILE

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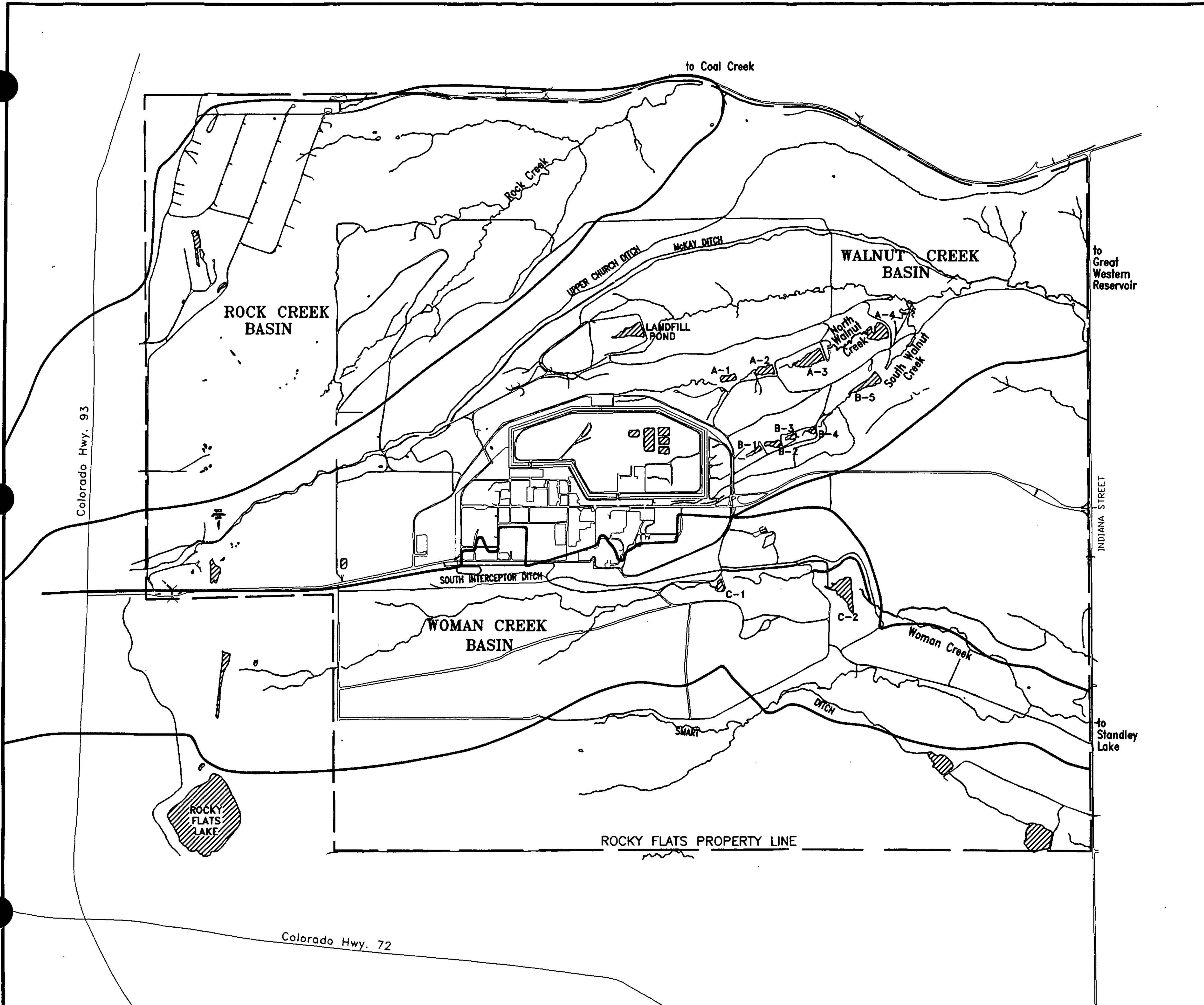
Land Use in the Vicinity of the Rocky Flats Plant

Figure 3-2

SEPTEMBER 1993

R74272a.PJ-090293/20C



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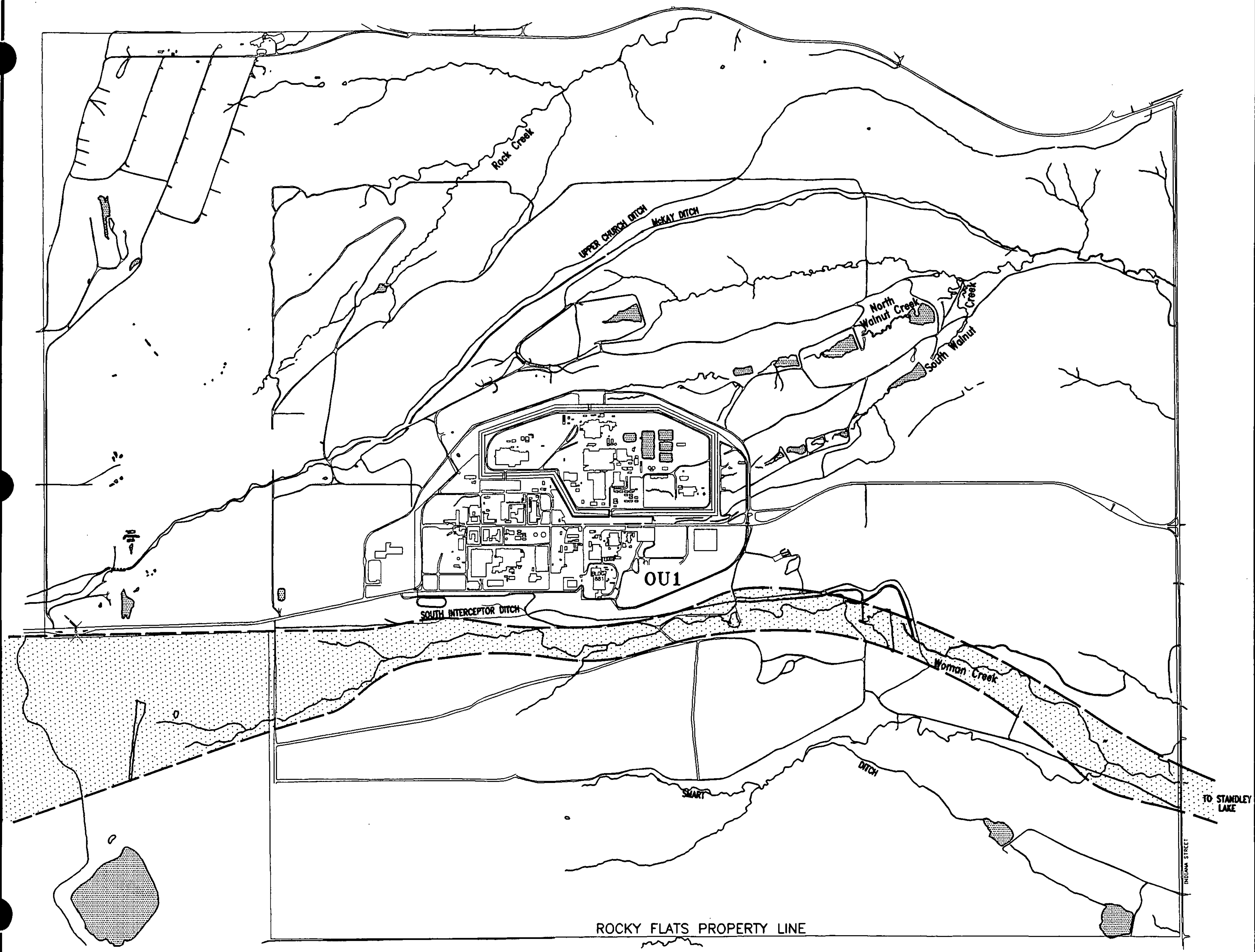
Principal Drainage Basins and Surface Water Features at Rocky flats Plant

Figure 3-4

OCTOBER 1992

R74041.MB071293



U.S. DEPARTMENT OF ENERGY
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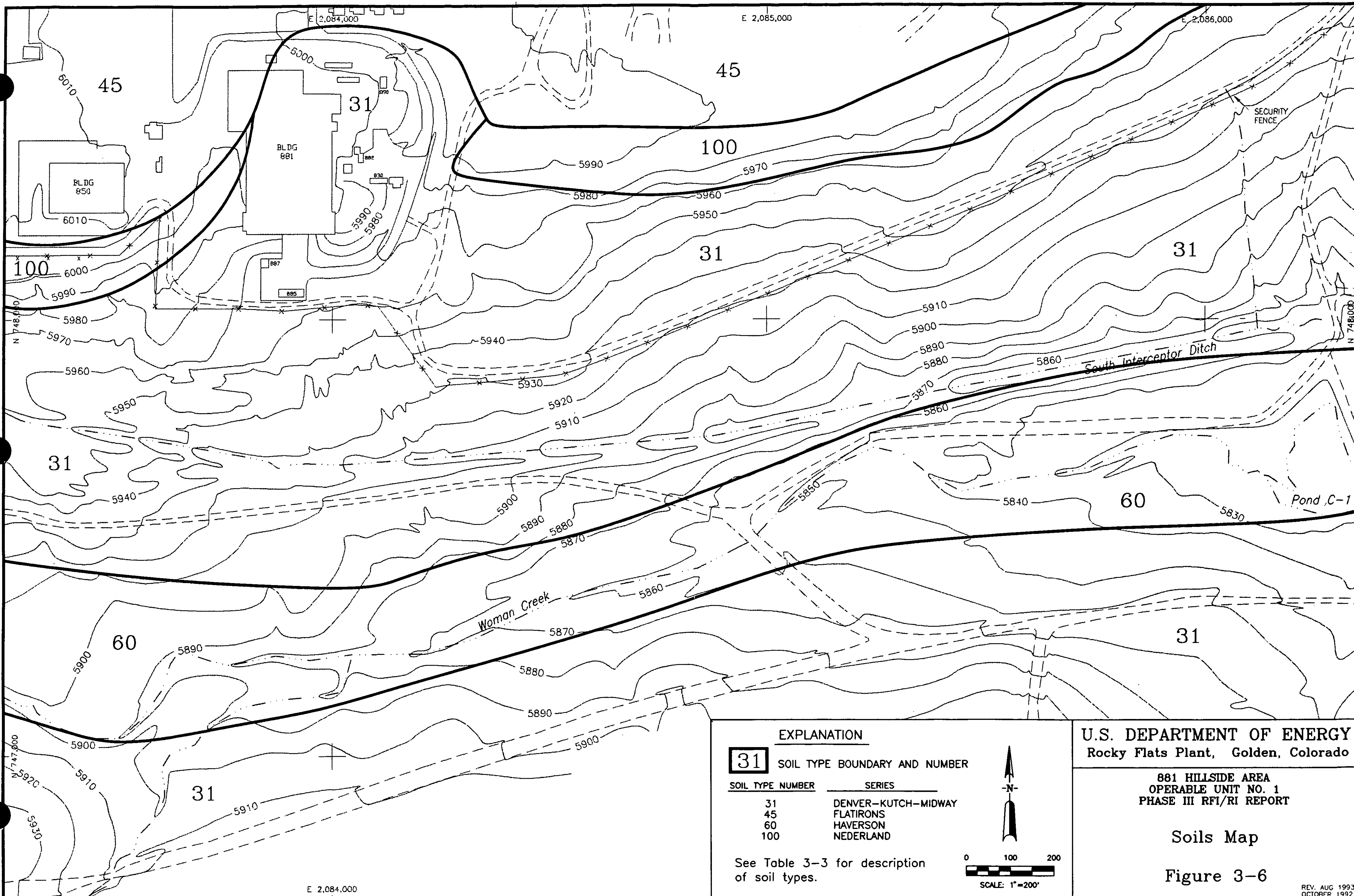
100-Year Flood Plain

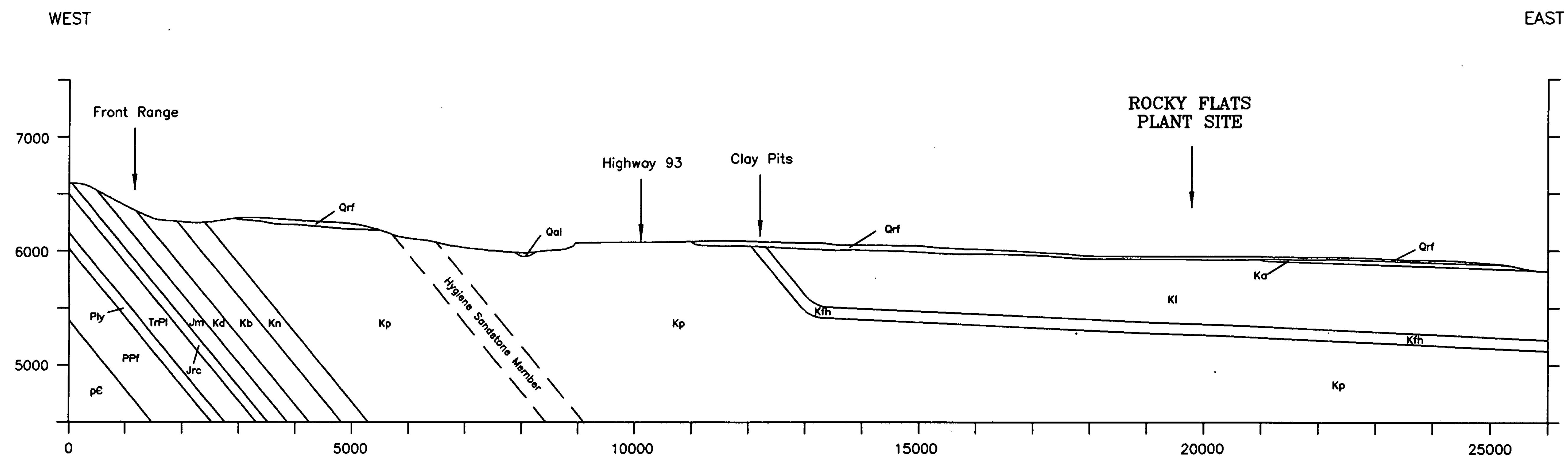
Figure 3-5

OCTOBER 1992

R74042.MB071293



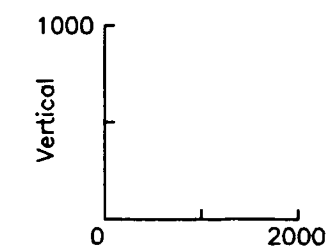
R74043.MB0806/200



EXPLANATION

Qrf = Quaternary Rocky Flats Alluvium
Qal = Quaternary Valley Fill Alluvium
Ka = Cretaceous Arapahoe Formation
Kl = Cretaceous Laramie Formation
Kfh = Cretaceous Fox Hills Sandstone
Kp = Cretaceous Pierre Shale
Kn = Cretaceous Niobrara Formation
Kb = Cretaceous Benton Shale
Kd = Cretaceous Dakota Group
Jm = Jurassic Morisson Formation
Jrc = Jurassic Ralston Creek Formation
TrPl = Permo–Triassic Lykins Formation
Ply = Permian Lyons Sandstone
PPf = Pennsylvanian–Permian Fountain Formation
p€ = Precambrian

After EG&G (1992c)



Horizontal
Scale in Feet
2X Vertical Exaggeration

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Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
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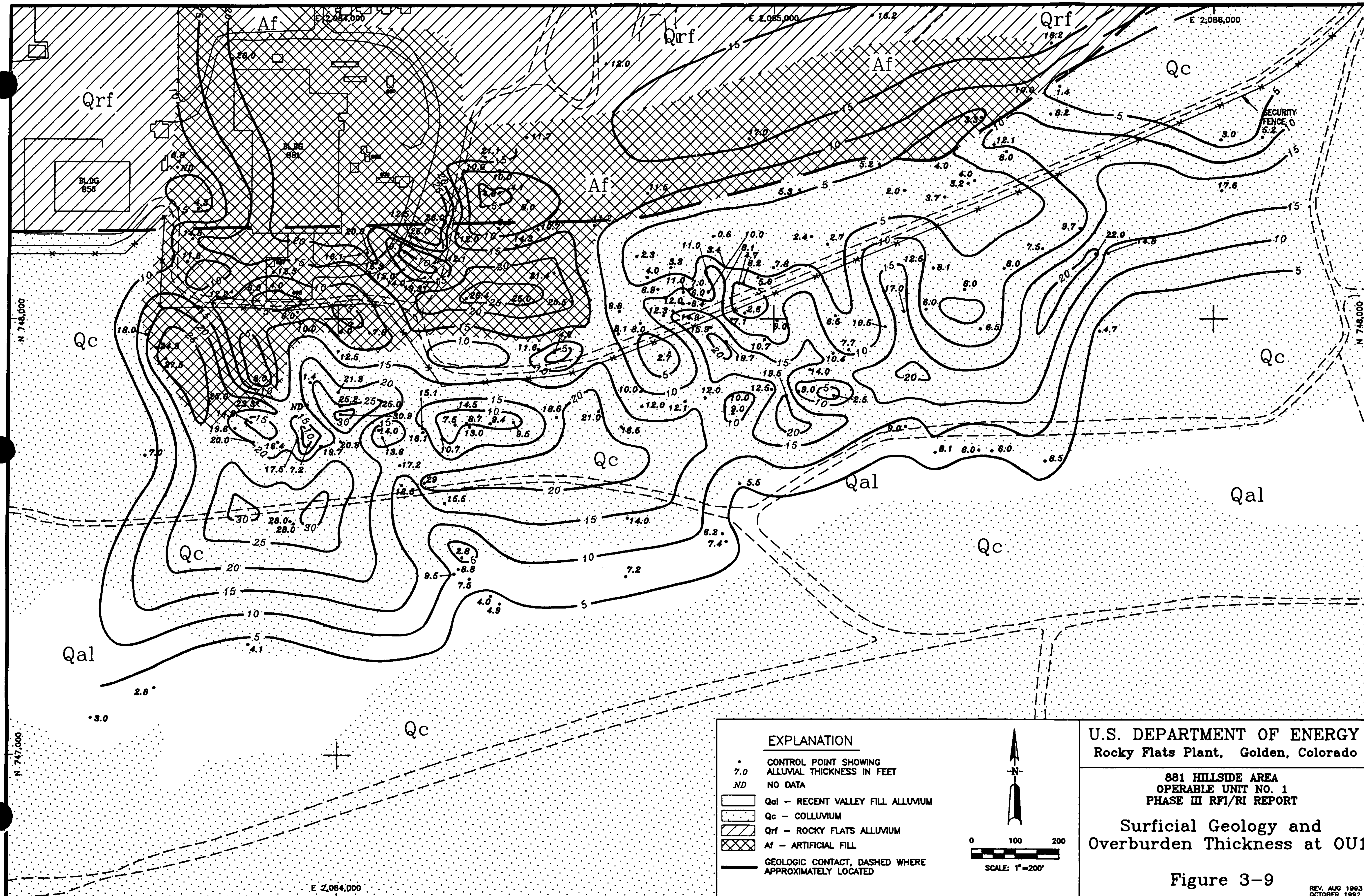
Generalized East–West
Cross Section,
Front Range to Rocky Flats

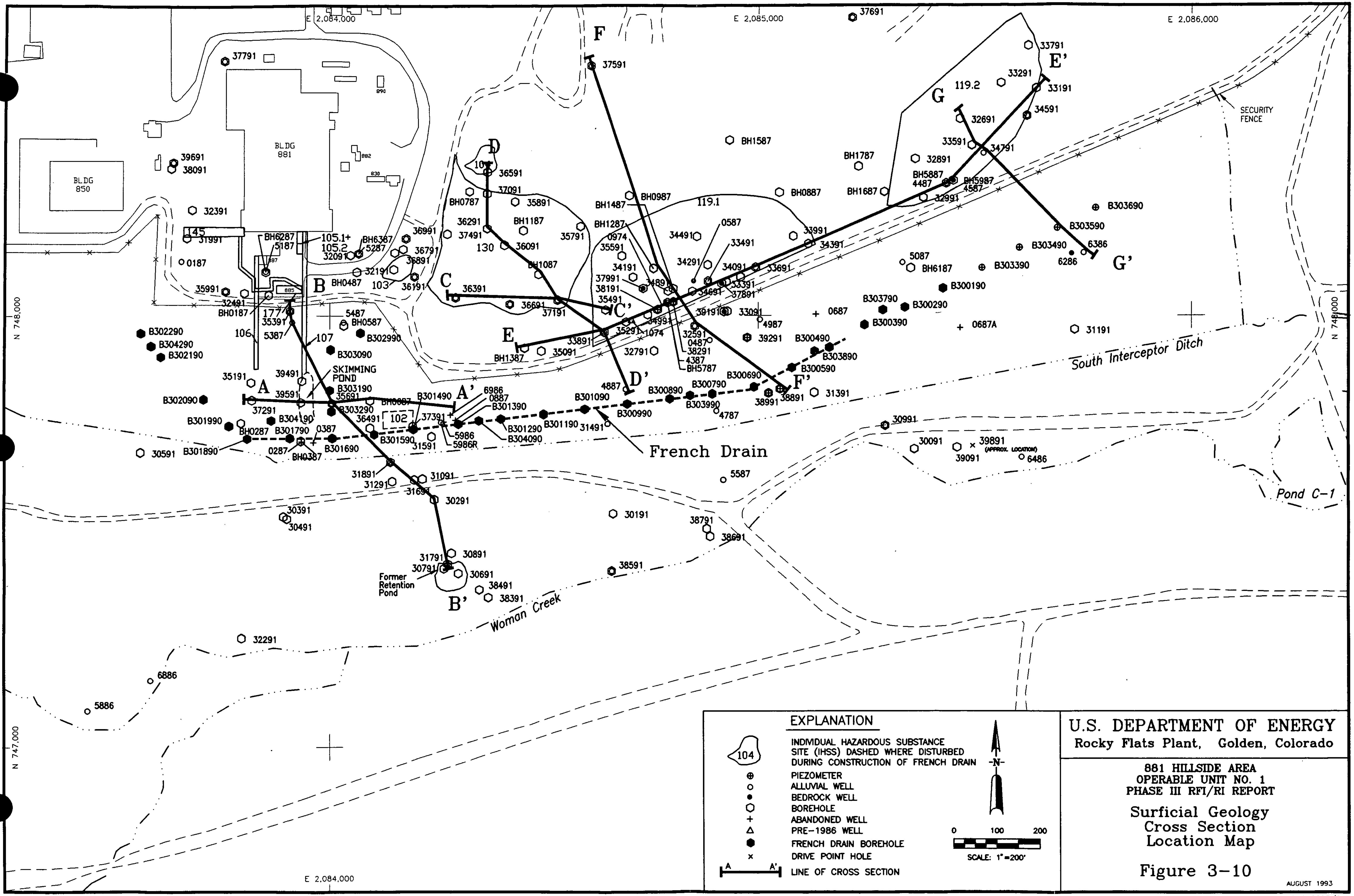
Figure 3–8

REV. JULY 1993
OCTOBER 1992

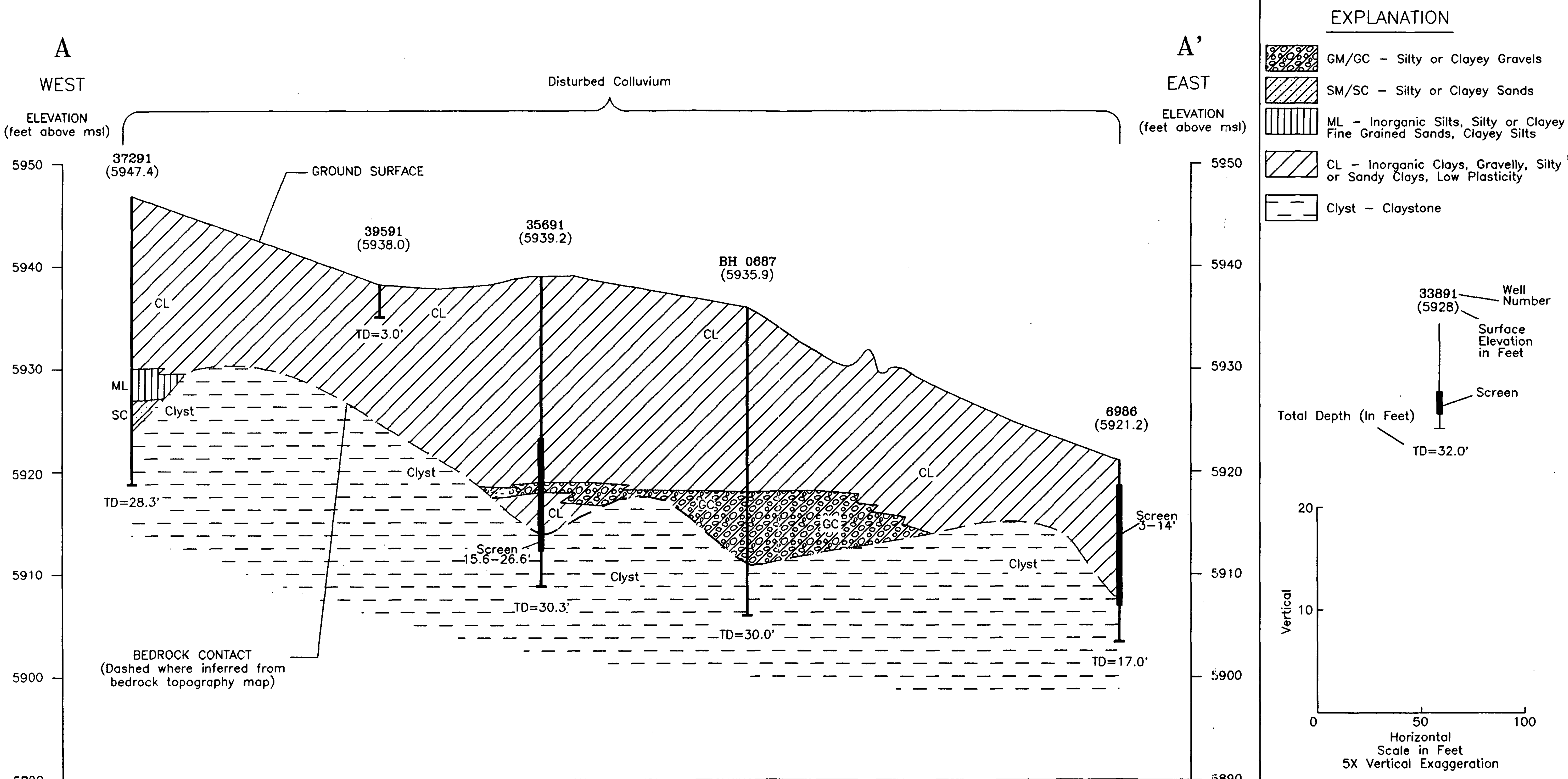
R74044.MB071293



R74018.MB080593/200



R74013.pj-082693/200



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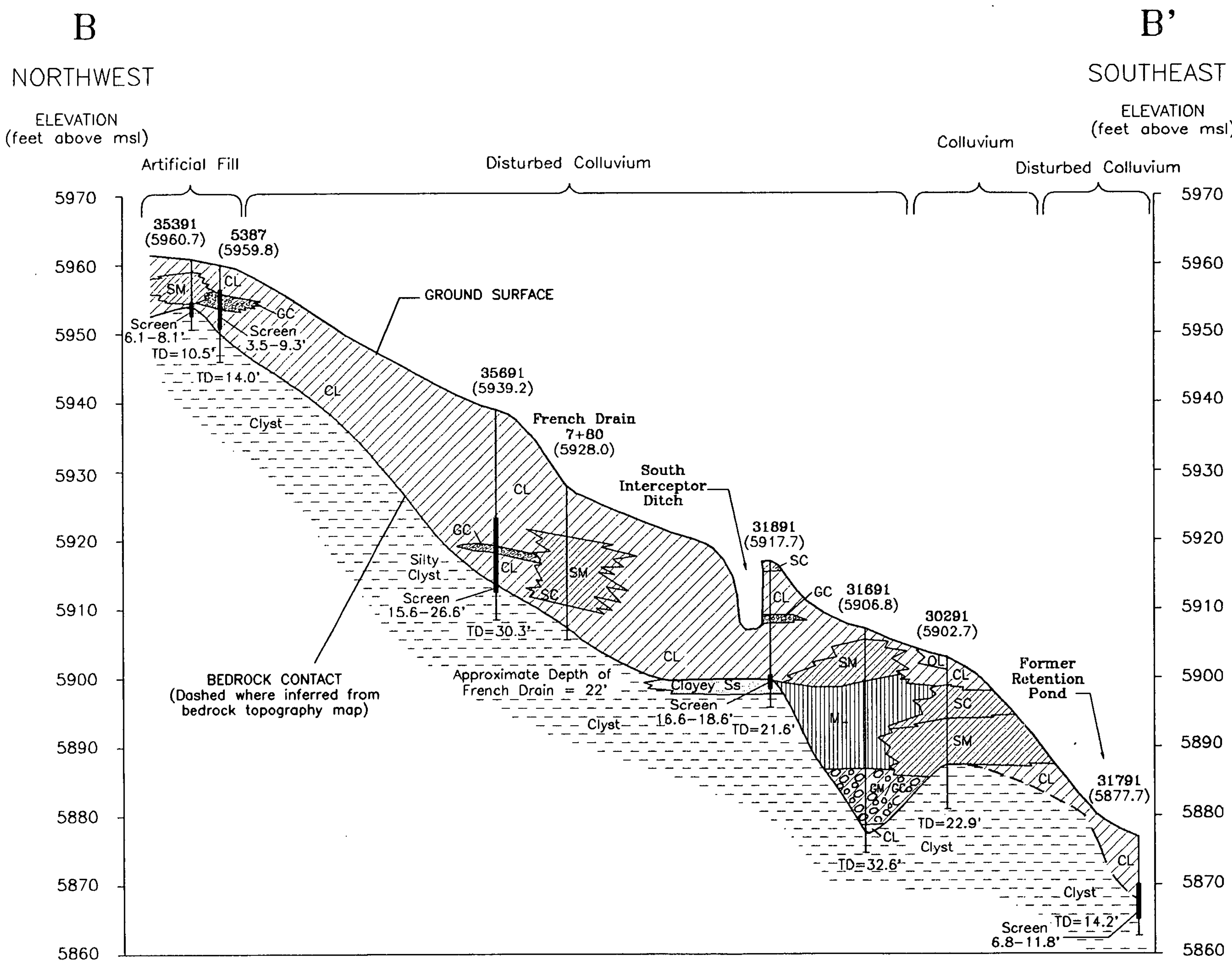
Surficial Geology Cross Section
A–A'
Figure 3–11

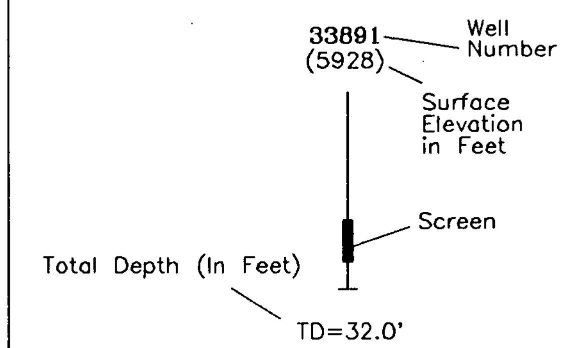
REV. AUG 1993
OCTOBER 1992

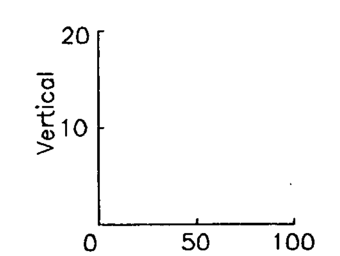
R74045.MBpj-082093



EXPLANATION

- GM/GC – Silty or Clayey Gravels
- SM/SC – Silty or Clayey Sands
- ML – Inorganic Silts, Silty or Clayey Fine Grained Sands, Clayey Silts
- CL – Inorganic Clays, Gravelly, Silty or Sandy Clays, Low Plasticity
- Clyst – Claystone
- Ss – Sandstone





Scale in Feet
5X Vertical Exaggeration

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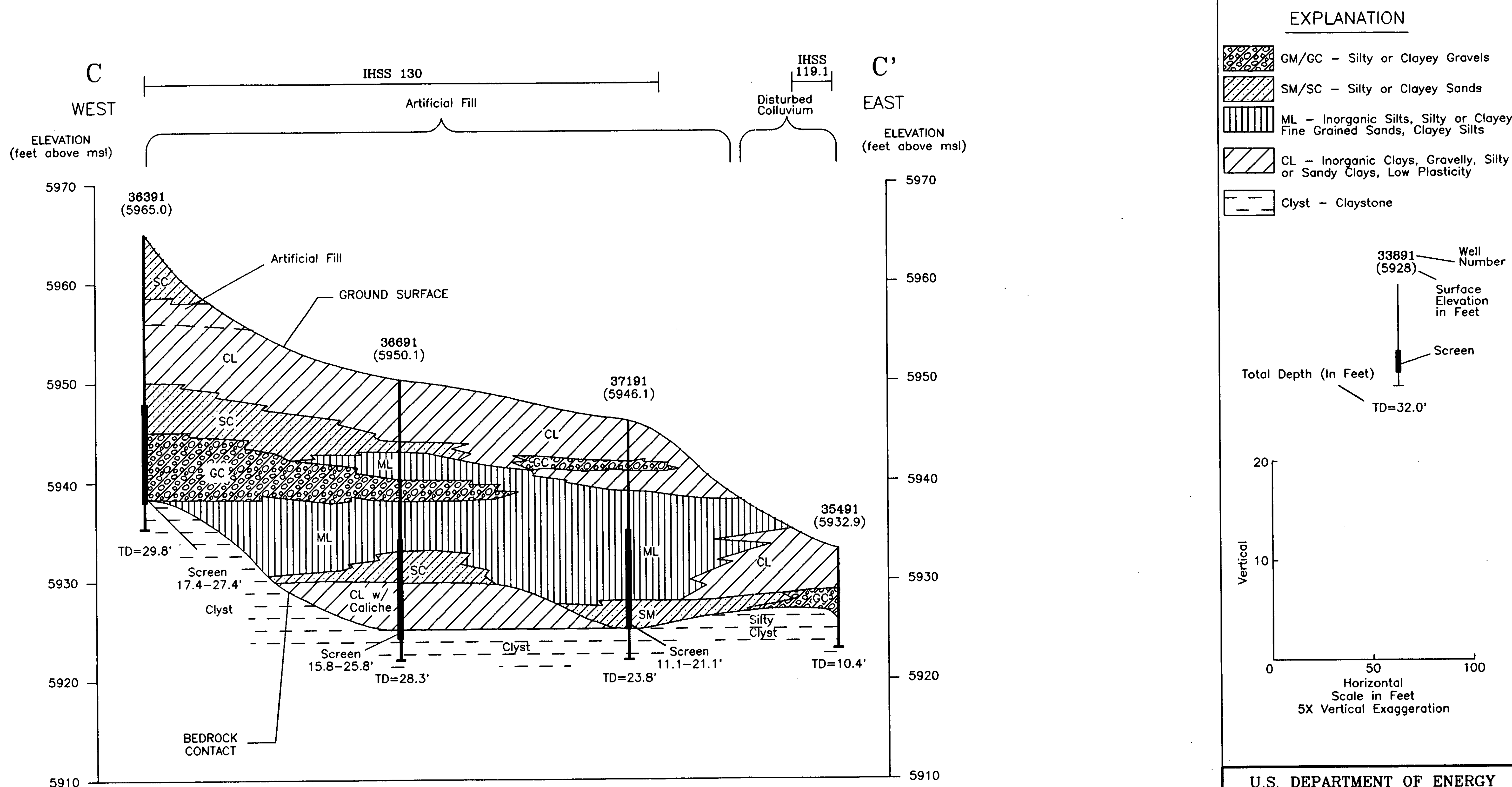
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Surficial Geology Cross Section B–B'

Figure 3-12

REV. OCTOBER 1993
OCTOBER 1992



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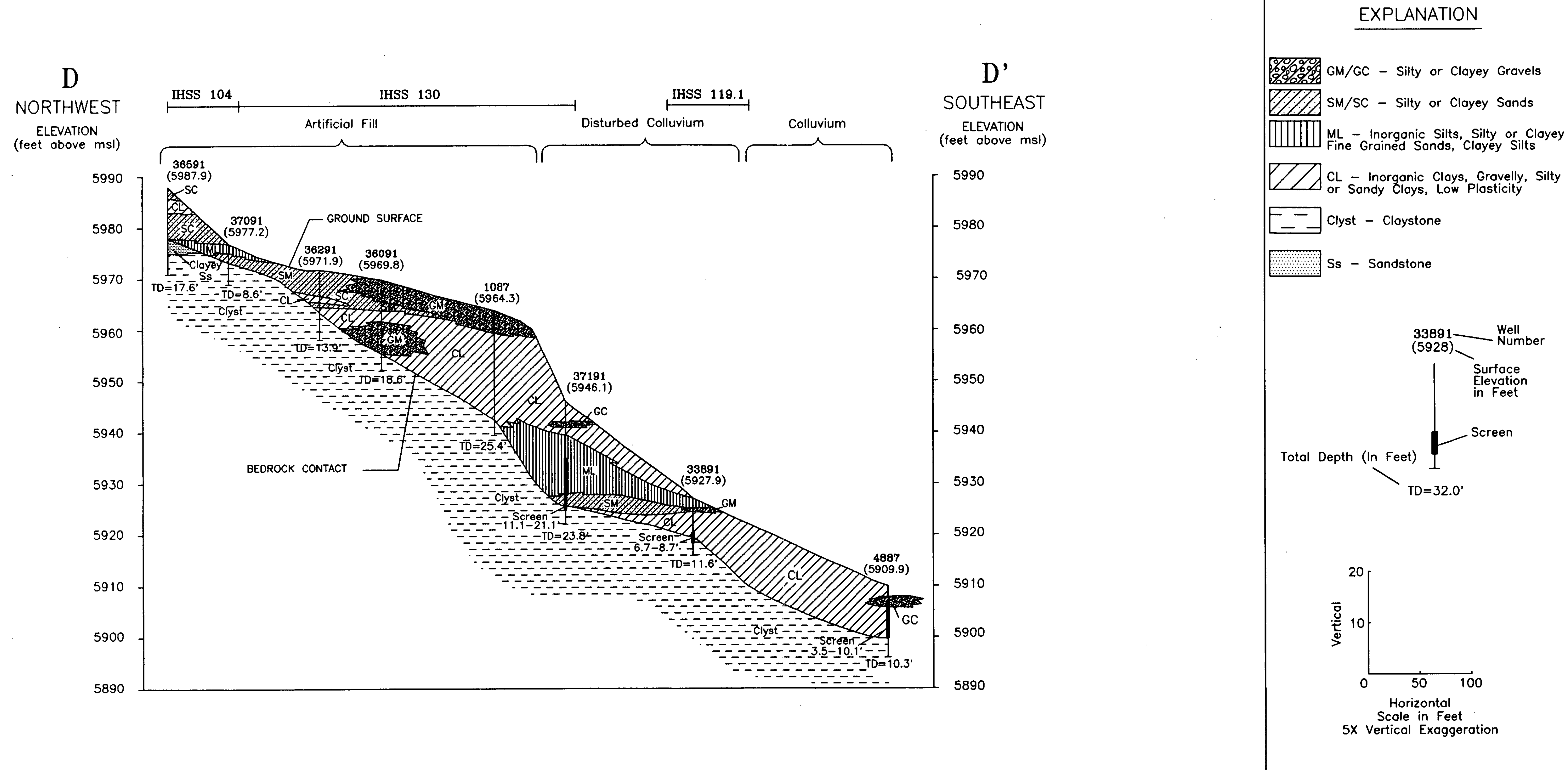
PHASE III RFI/RI REPORT

Surficial Geology Cross Section
C–C'
Figure 3–13

REV. AUG 1993
OCTOBER 1992

R74035.MBpi-062693



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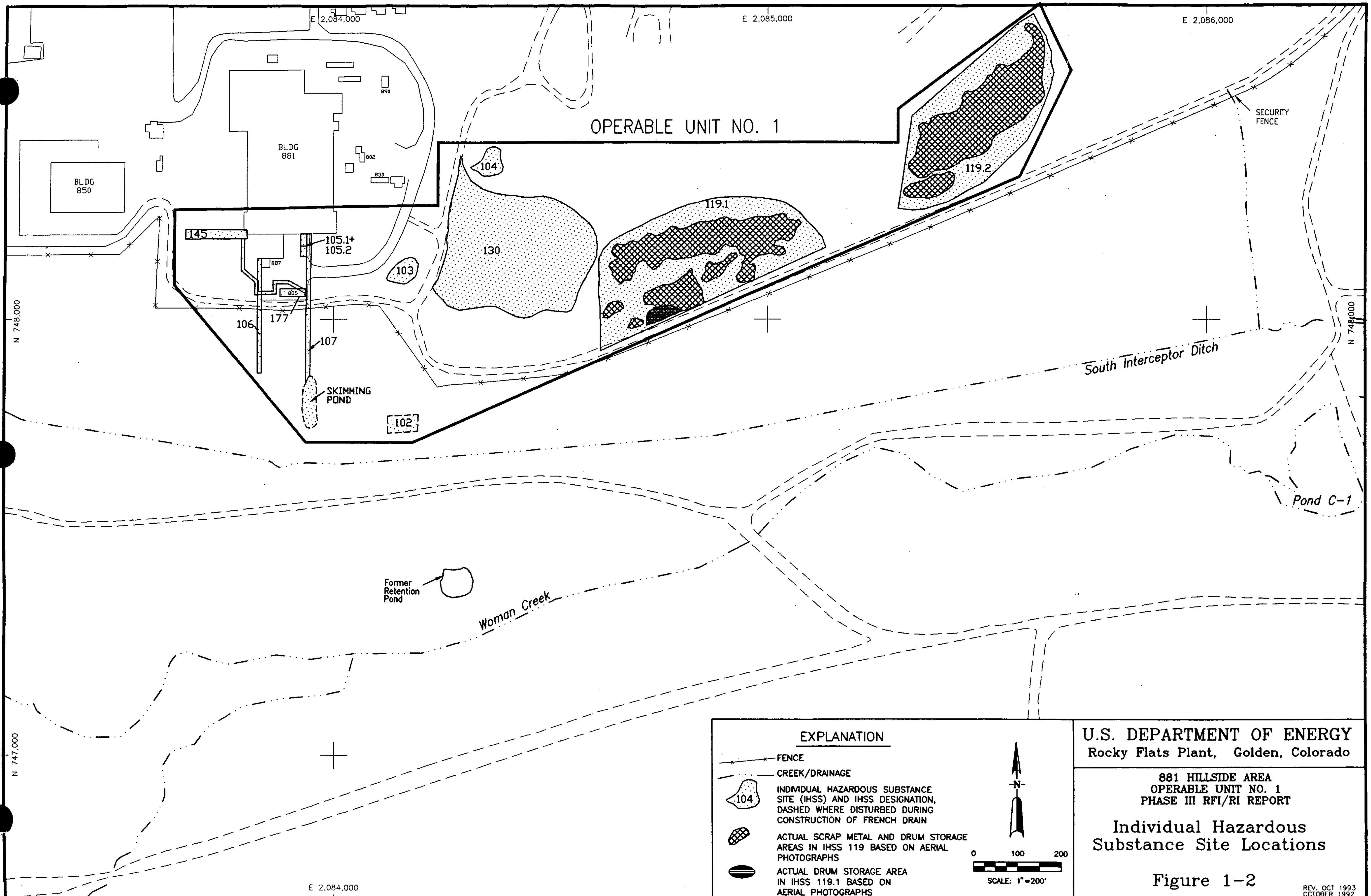
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Surficial Geology Cross Section D–D'

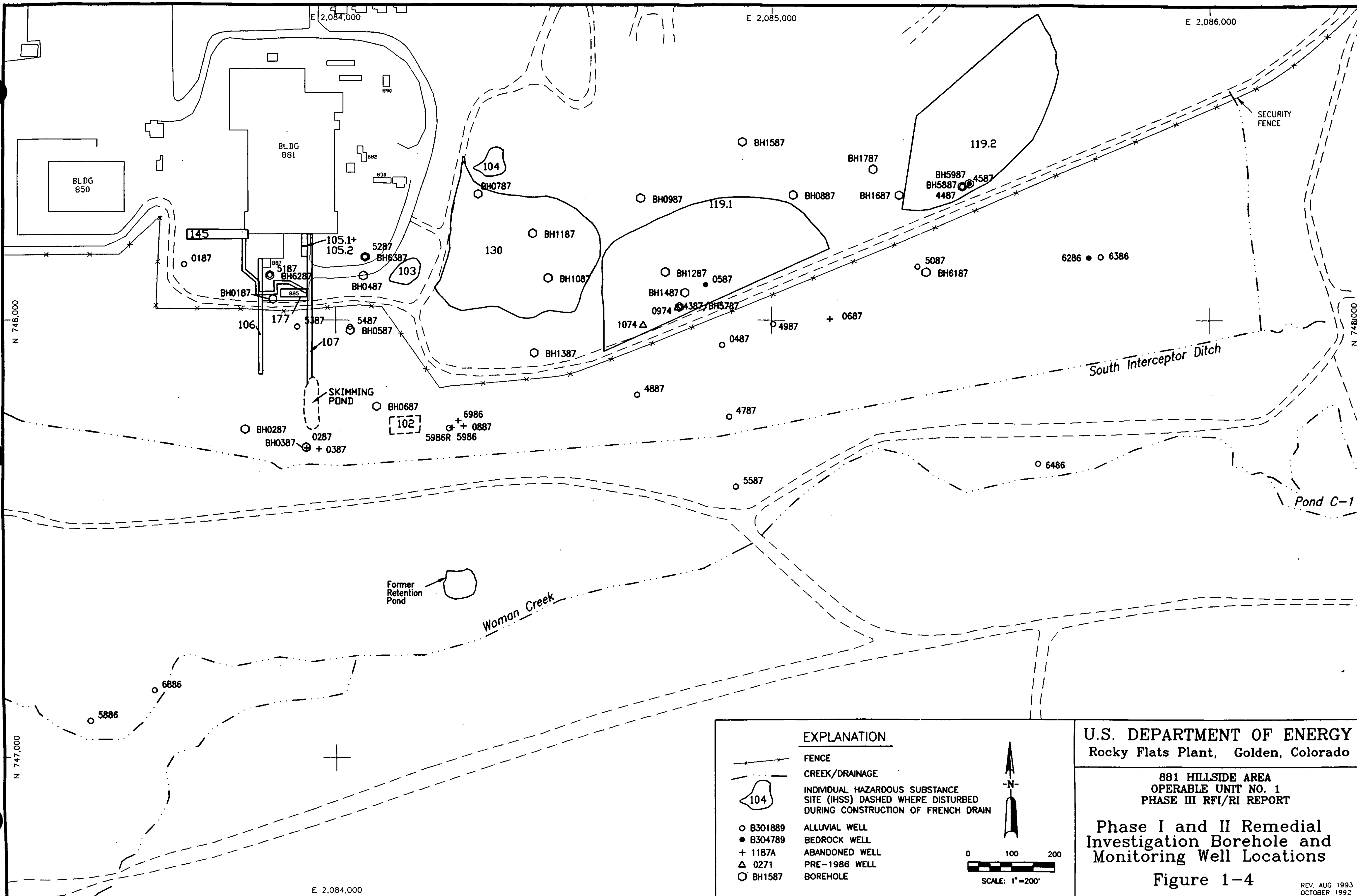
Figure 3-14

REV. AUG 1993
OCTOBER 1992

R74034.MBpi-062693



R74011.MBPJ-102293/200



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Rocky Flats Plant, Golden, Colorado

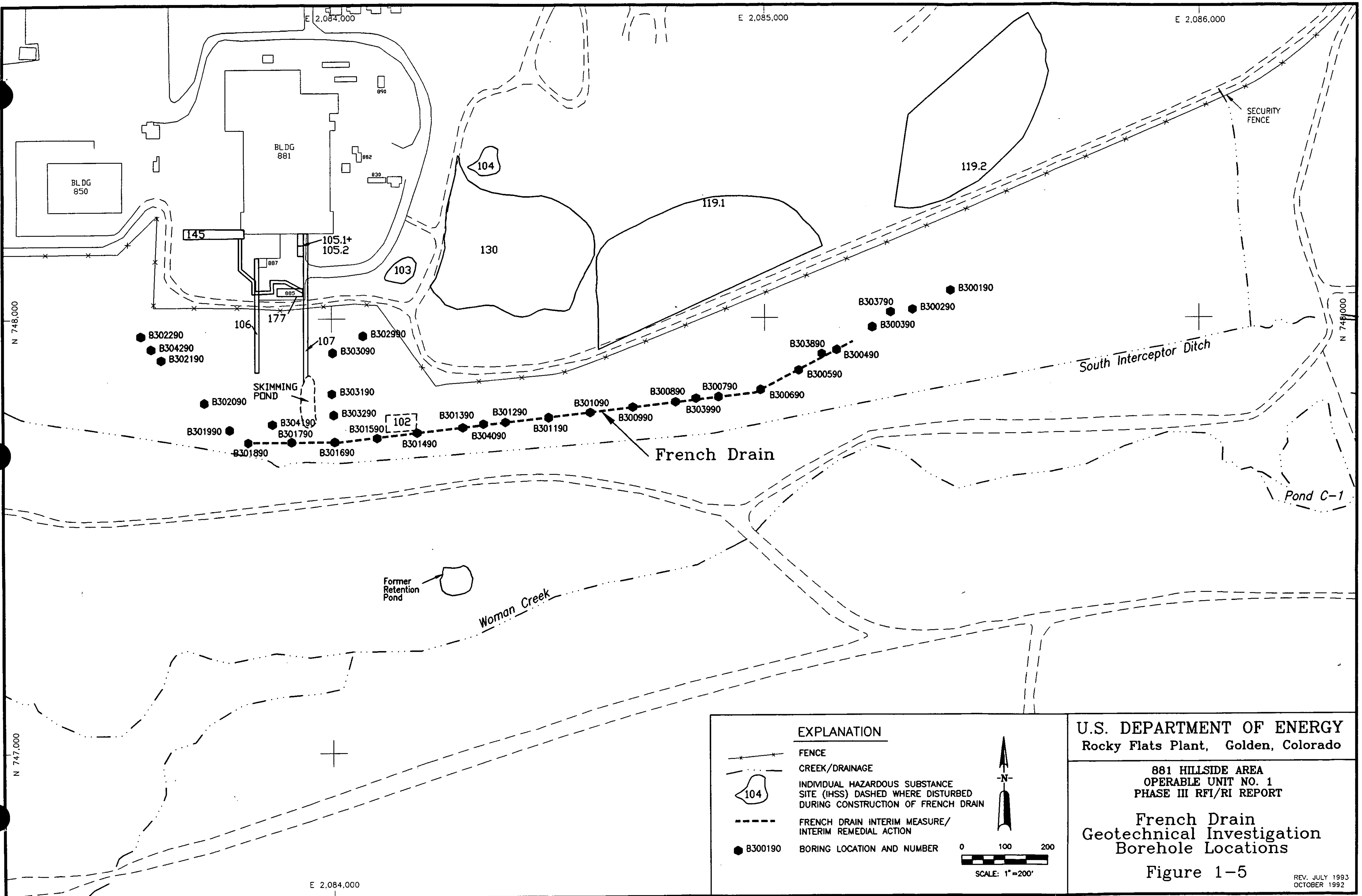
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Phase I and II Remedial Investigation Borehole and Monitoring Well Locations

Figure 1-4

REV. AUG 1993
OCTOBER 1992

R74064.MBMB102693/200



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Rocky Flats Plant, Golden, Colorado

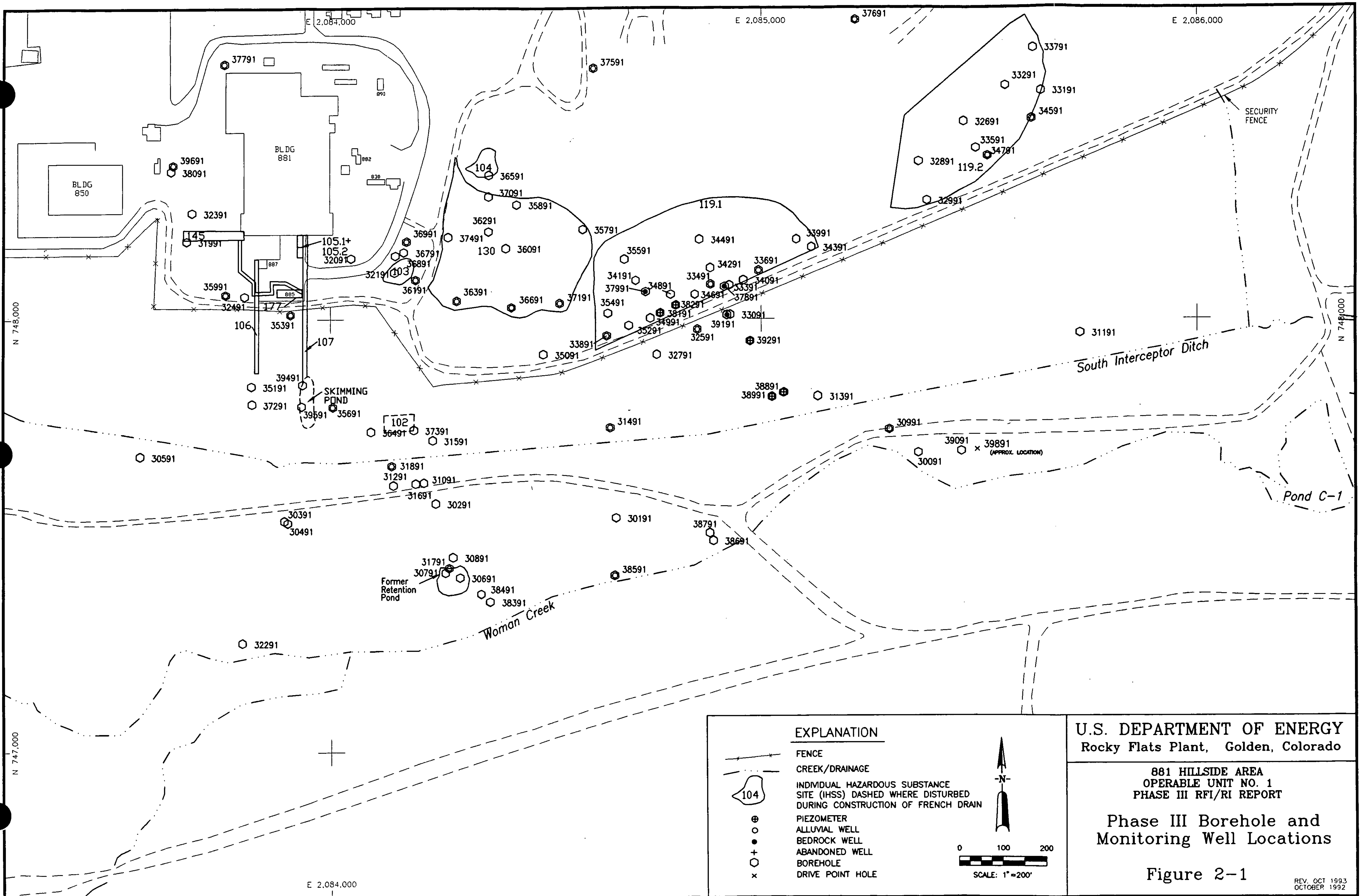
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

French Drain
Geotechnical Investigation
Borehole Locations

Figure 1-5

REV. JULY 1993
OCTOBER 1992

R74065.MBMB102693/200



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Rocky Flats Plant, Golden, Colorado

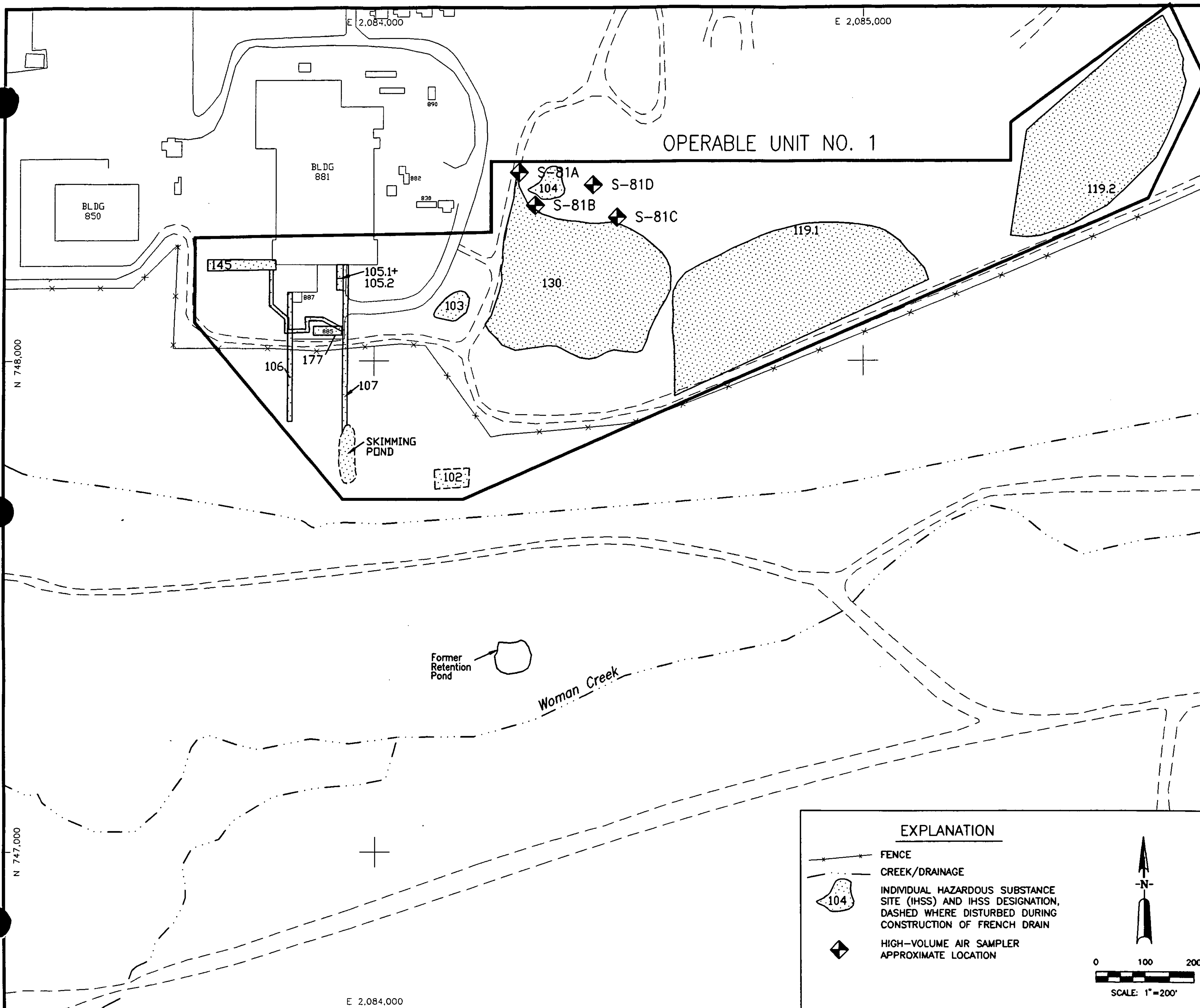
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Phase III Borehole and Monitoring Well Locations

Figure 2-1

REV. OCT 1993
OCTOBER 1992

R74012.MBmb102693/200



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Rocky Flats Plant, Golden, Colorado

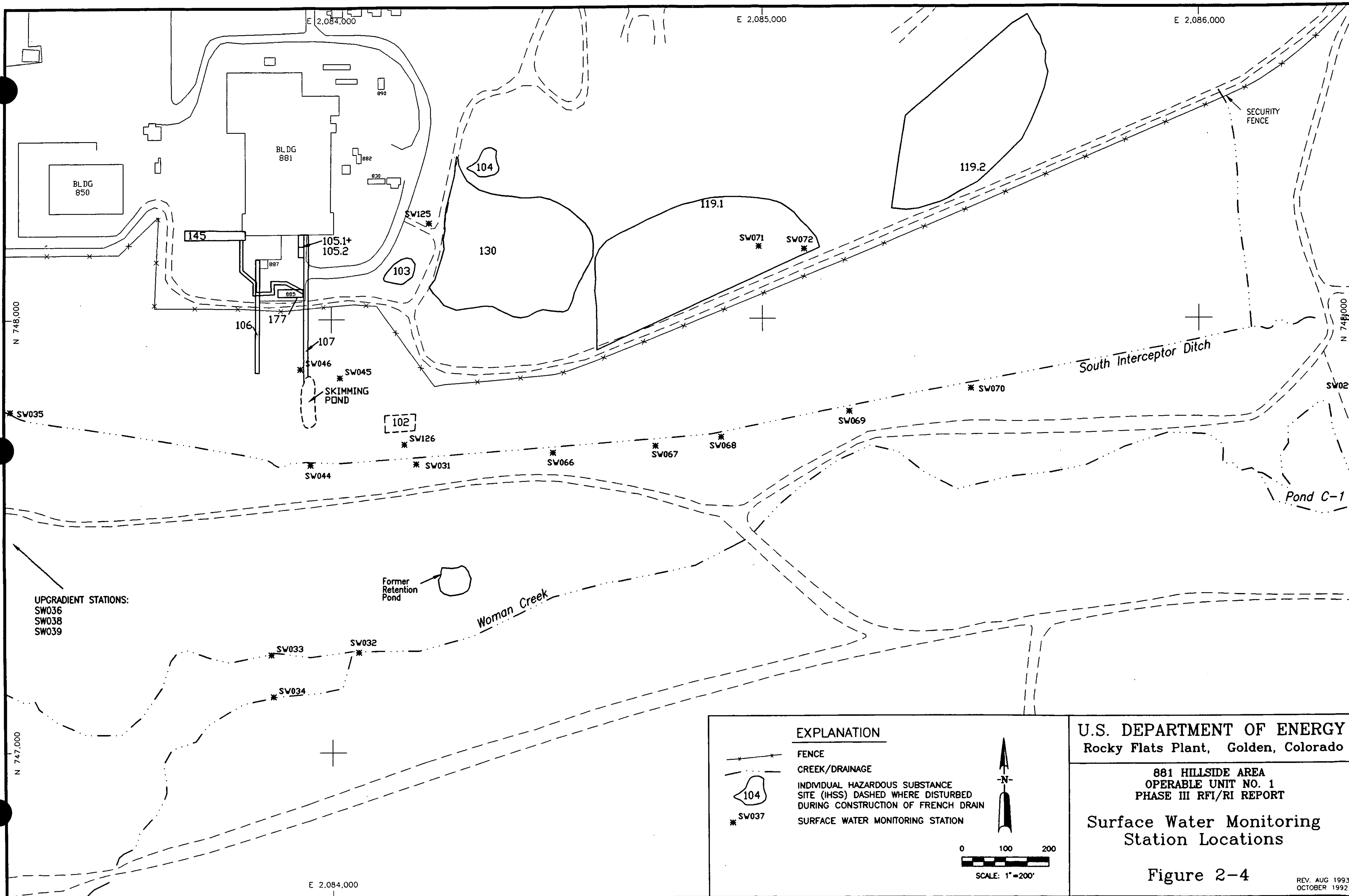
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

0U1 High-Volume Air Sampler Locations

Figure 2-3

REV. AUG 1993
OCTOBER 1992

R74066.MBMB102693/200



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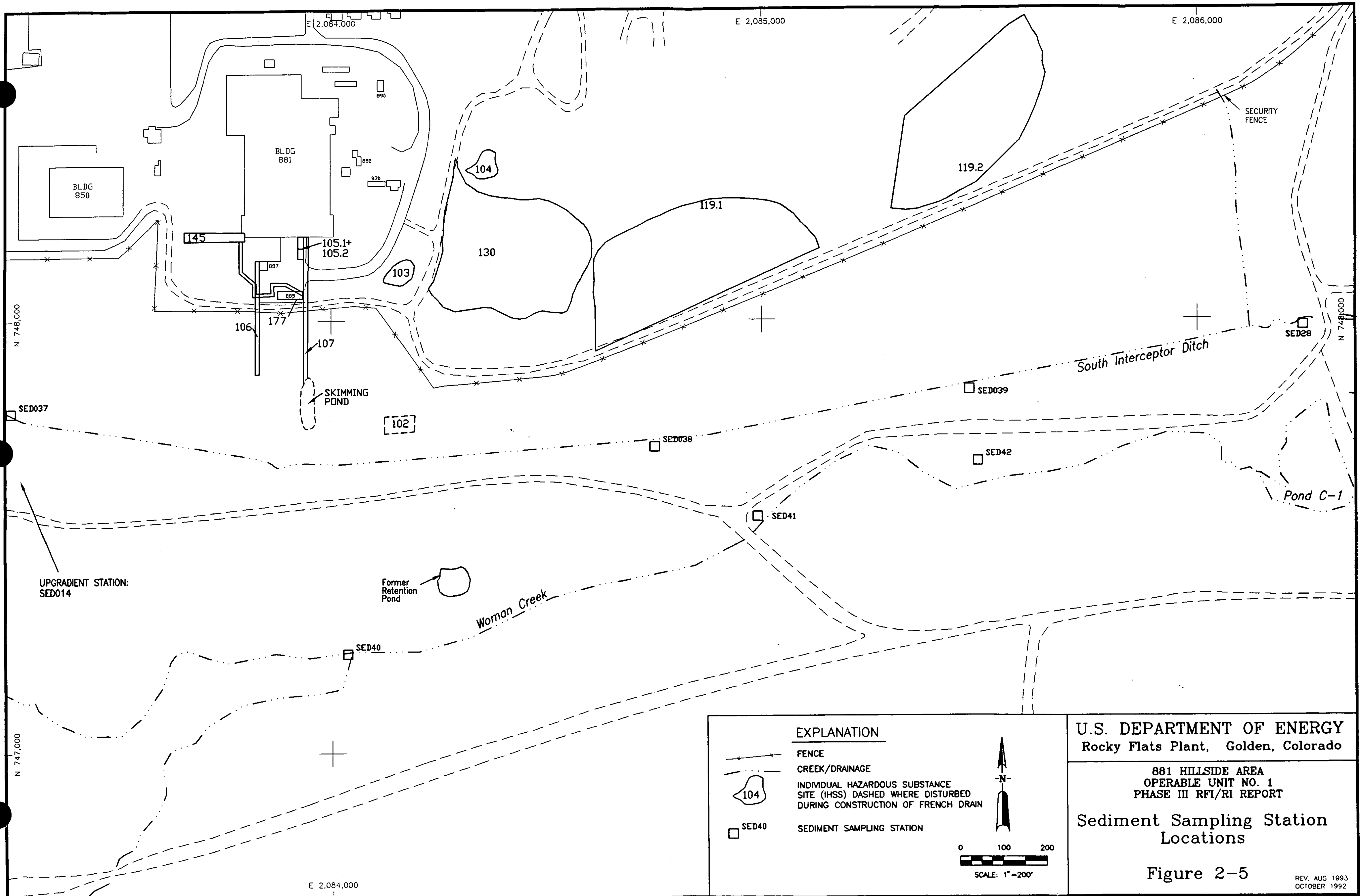
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Surface Water Monitoring Station Locations

Figure 2-4

REV. AUG 1993
OCTOBER 1992

R74032.MBMB102693/200



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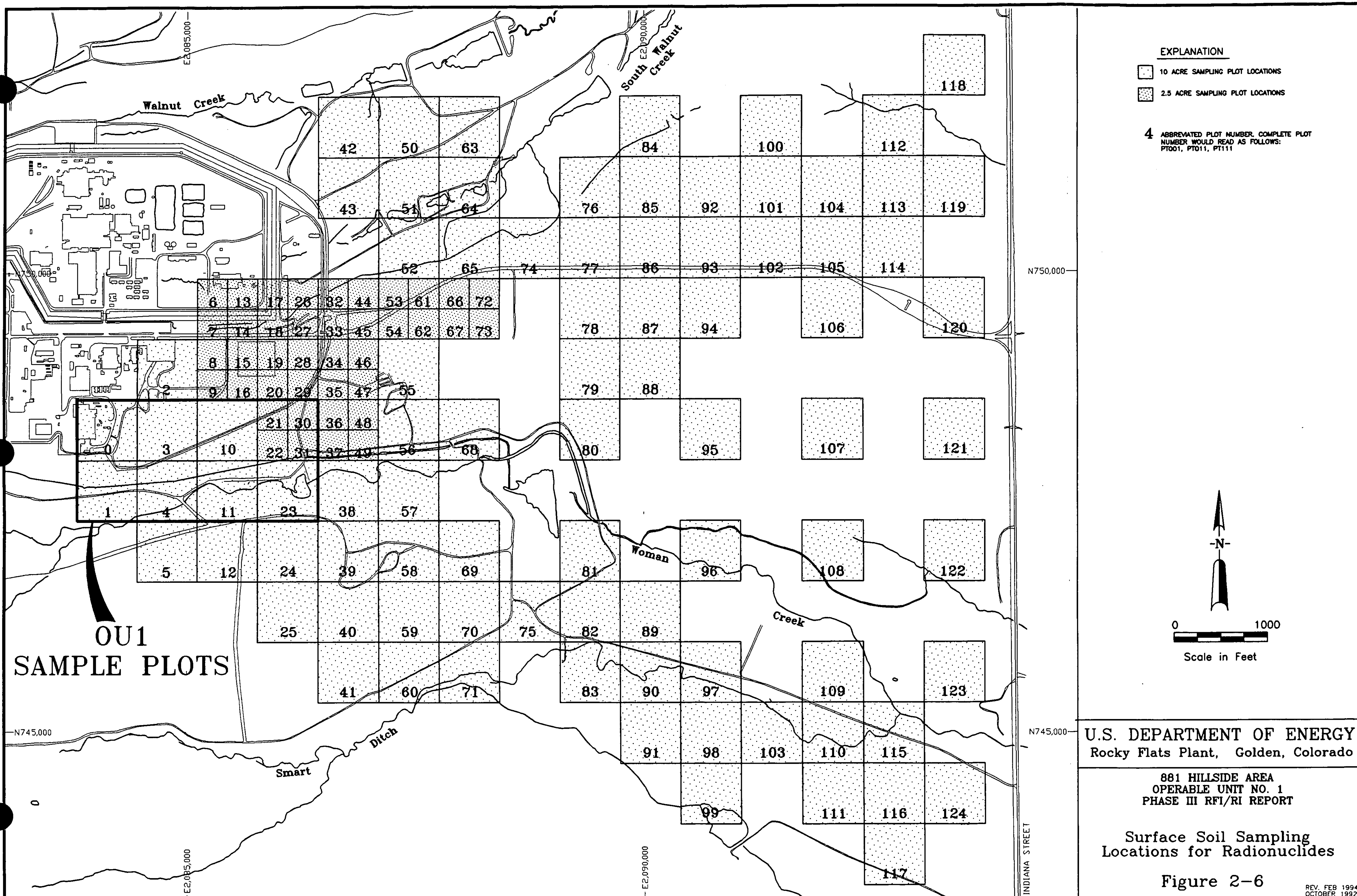
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Sediment Sampling Station Locations

Figure 2-5

REV. AUG 1993
OCTOBER 1992

R74067.MBMB102693/200



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Rocky Flats Plant, Golden, Colorado

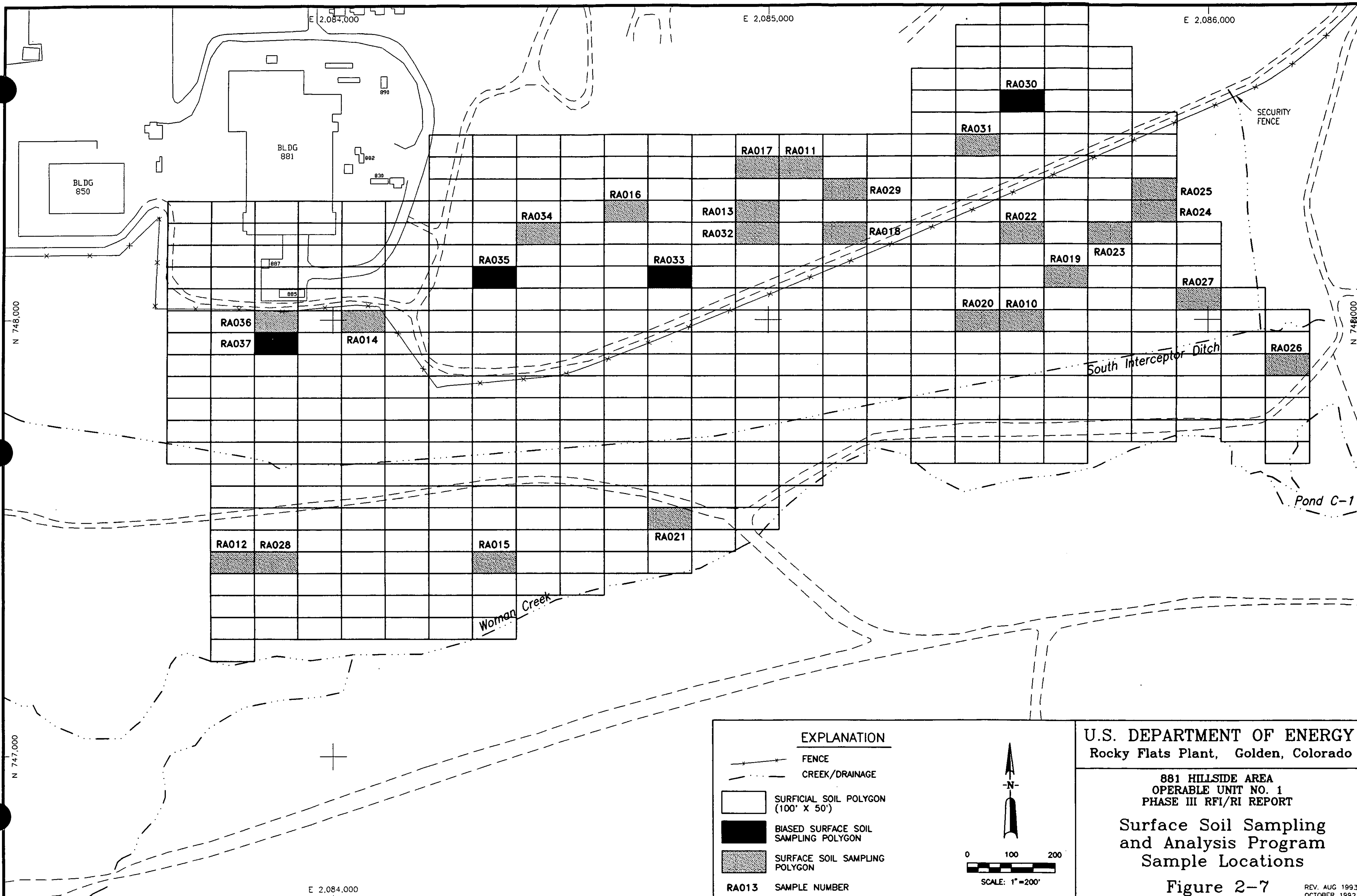
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Surface Soil Sampling Locations for Radionuclides

Figure 2-6

REV. FEB 1994
OCTOBER 1992

R74259.MBMB020494/950



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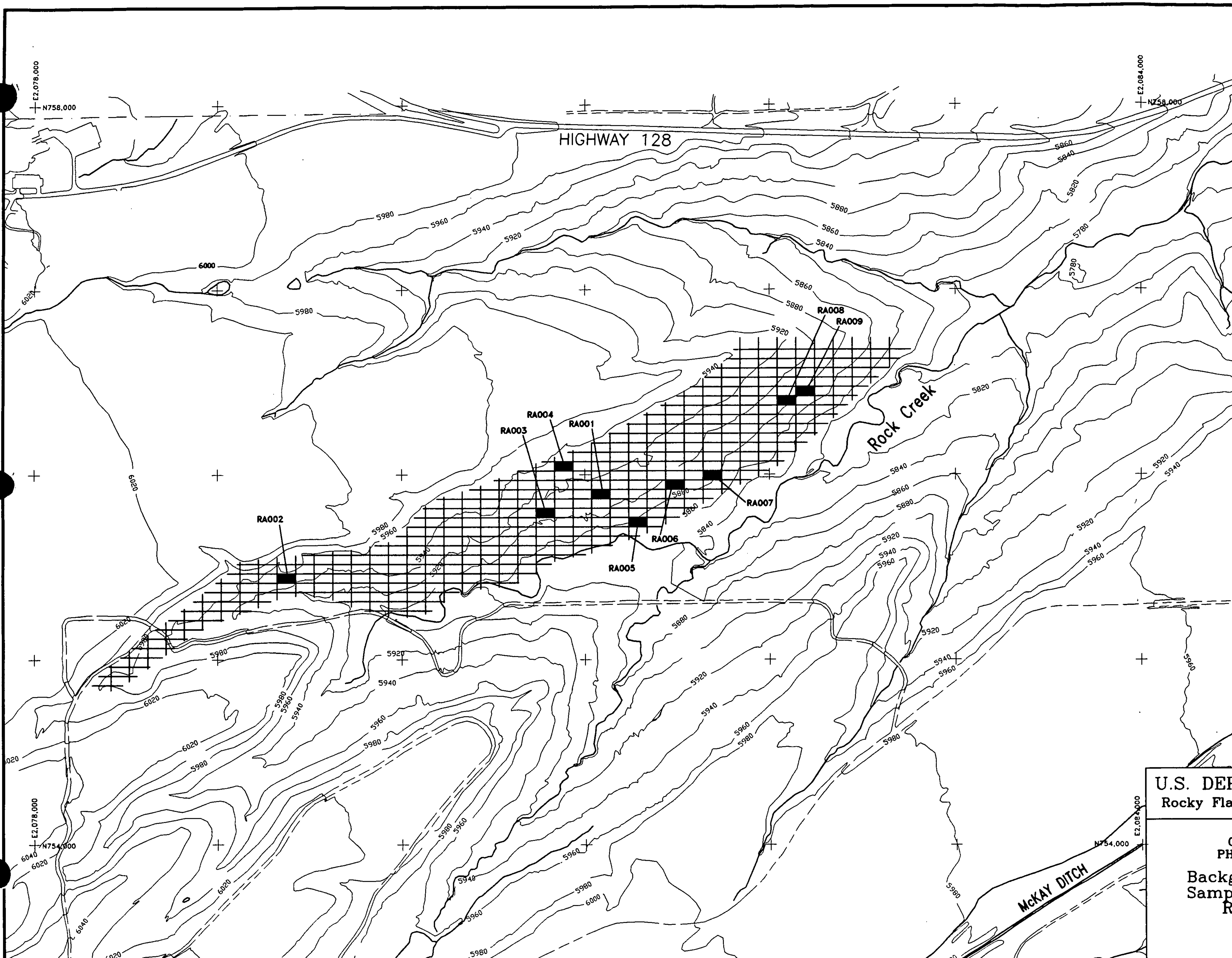
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Surface Soil Sampling and Analysis Program Sample Locations

Figure 2-7

REV. AUG 1993
OCTOBER 1992

R74260.MBMB102693/200



EXPLANATION

SURFICIAL SOIL POLYGON (100' x 50')

BACKGROUND SURFACE SOIL SAMPLING LOCATIONS

RA009 SAMPLE NUMBER

N

0 500

SCALE: 1"=500'

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Rocky Flats Plant, Golden, Colorado

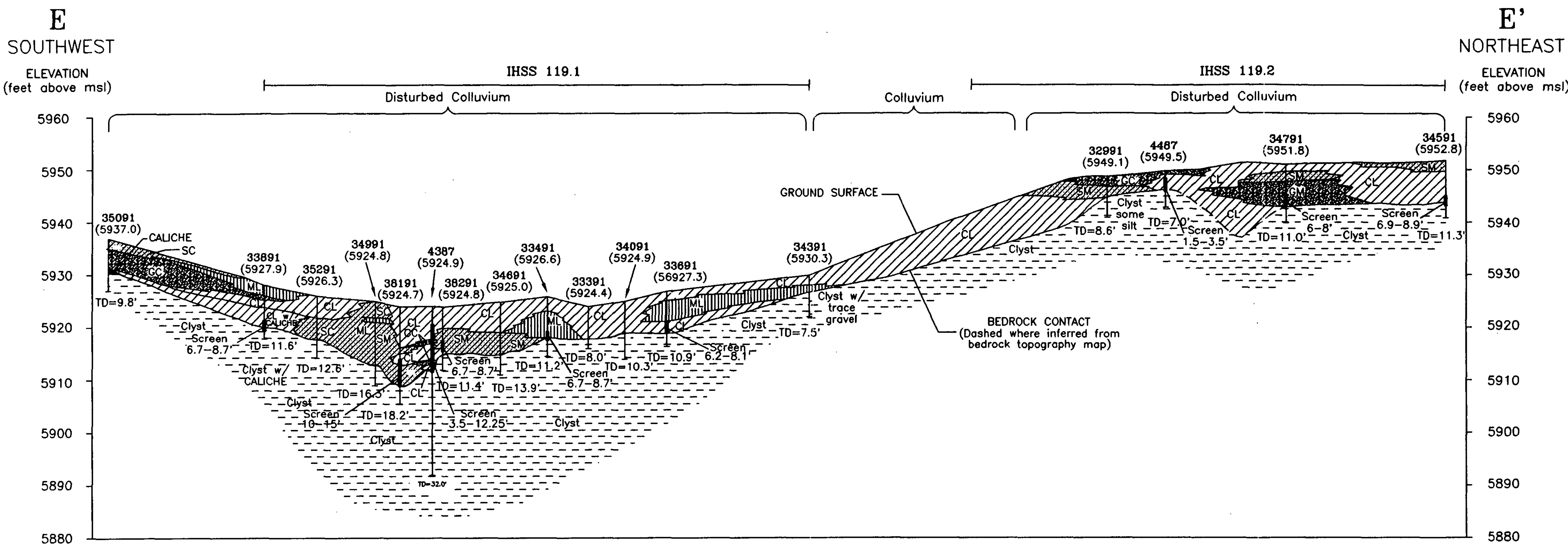
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Background Surface Soil Sample Locations in the Rock Creek Area

Figure 2-8

REV. JULY 1993
OCTOBER 1992

R74261.MBMB102693/500



EXPLANATION

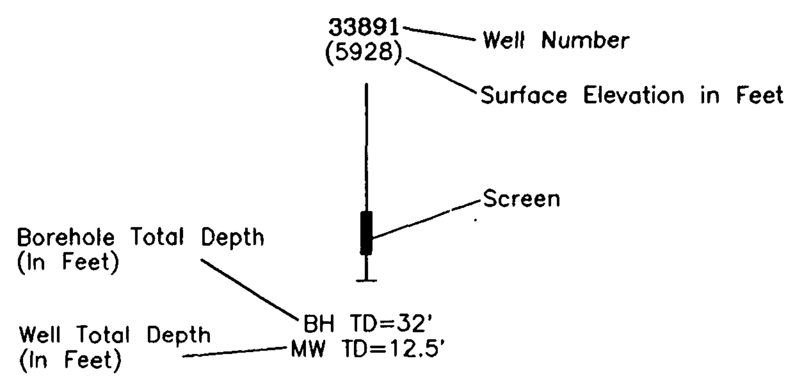
GM/GC – Silty or Clayey Gravels

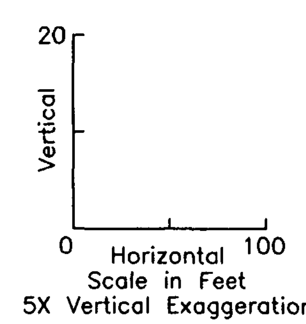
SM/SC – Silty or Clayey Sands

ML – Inorganic Silts, Silty or Clayey Fine Grained Sands, Clayey Silts

CL – Inorganic Clays, Gravelly, Silty or Sandy Clays, Low Plasticity

Clyst – Claystone





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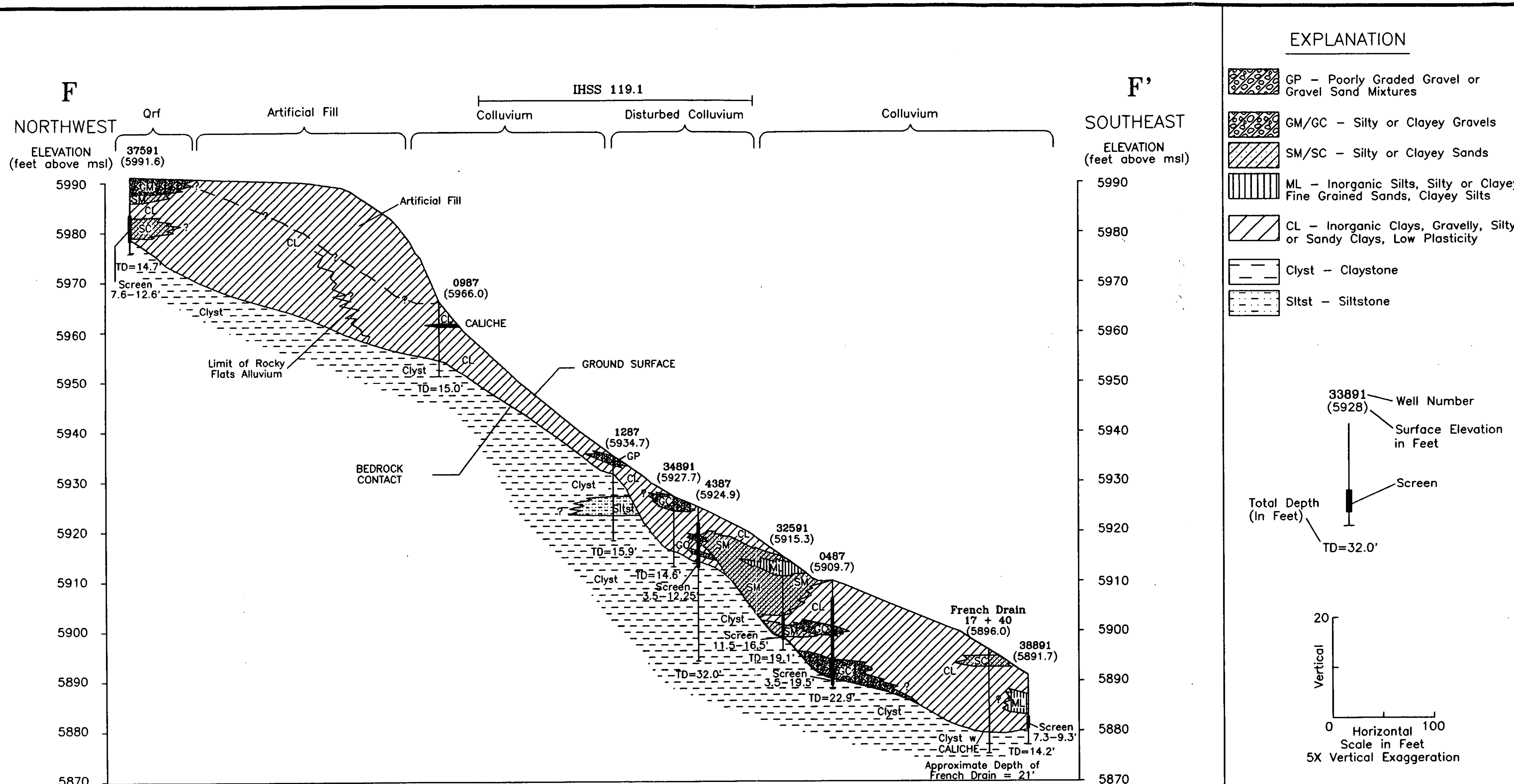
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Surficial Geology Cross Section
E–E'
Figure 3–15

REV. AUG 1993
OCTOBER 1992

R74046.MBpl



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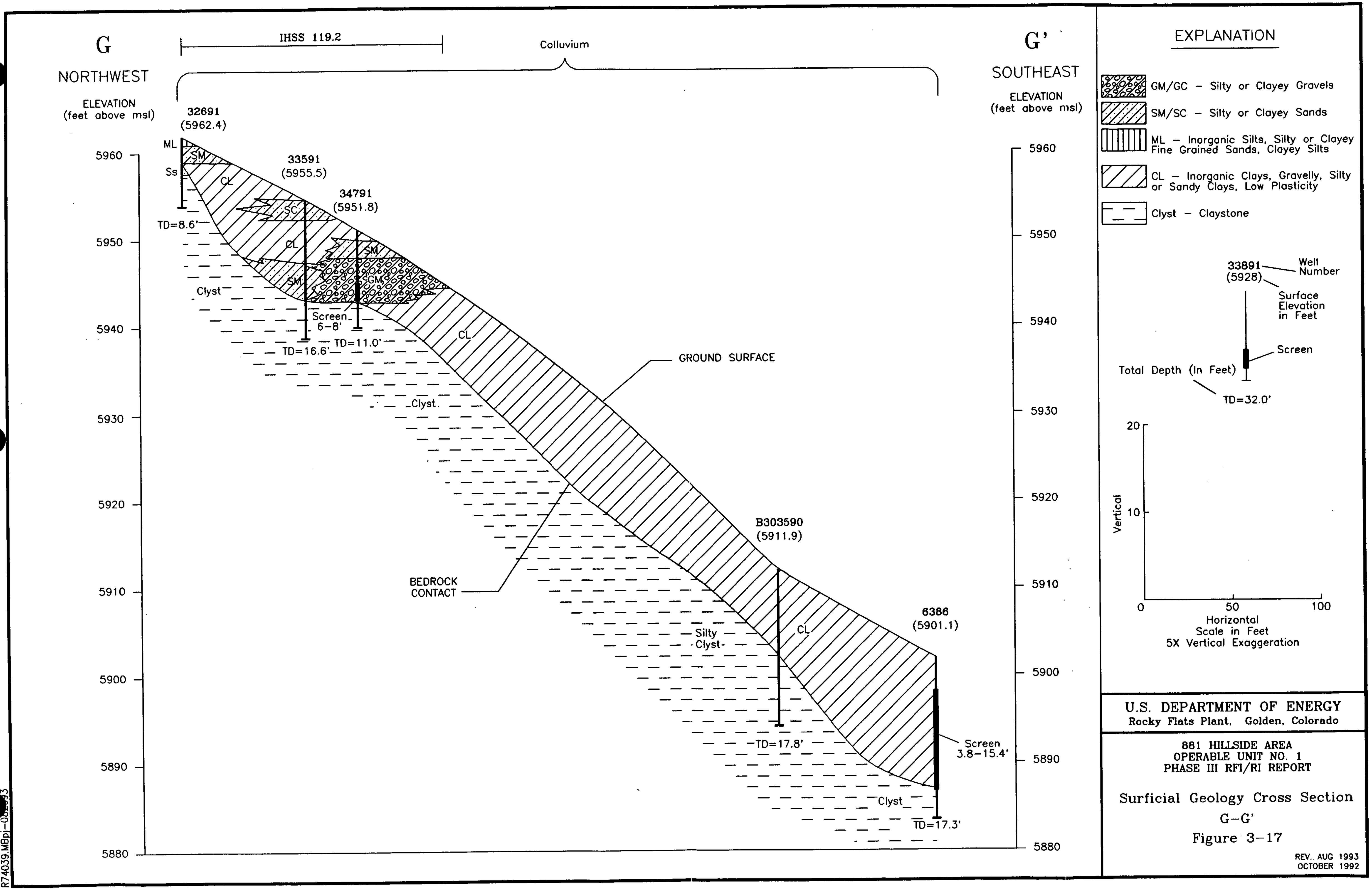
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Surficial Geology Cross Section
F-F'
Figure 3-16

REV. AUG 1993
OCTOBER 1992

R74040.MBpi-062093



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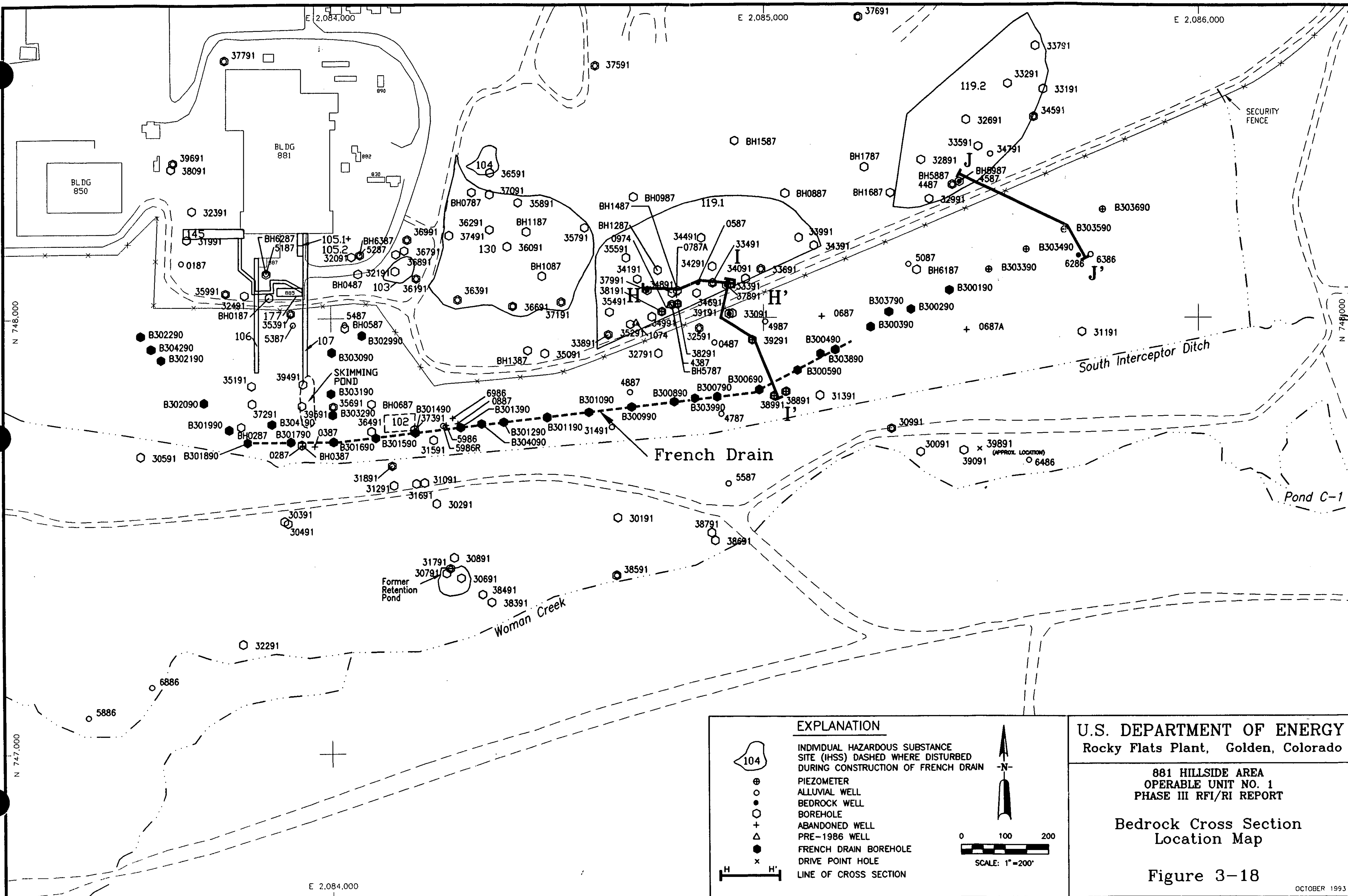
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Surficial Geology Cross Section
G–G'
Figure 3–17

REV. AUG 1993
OCTOBER 1992



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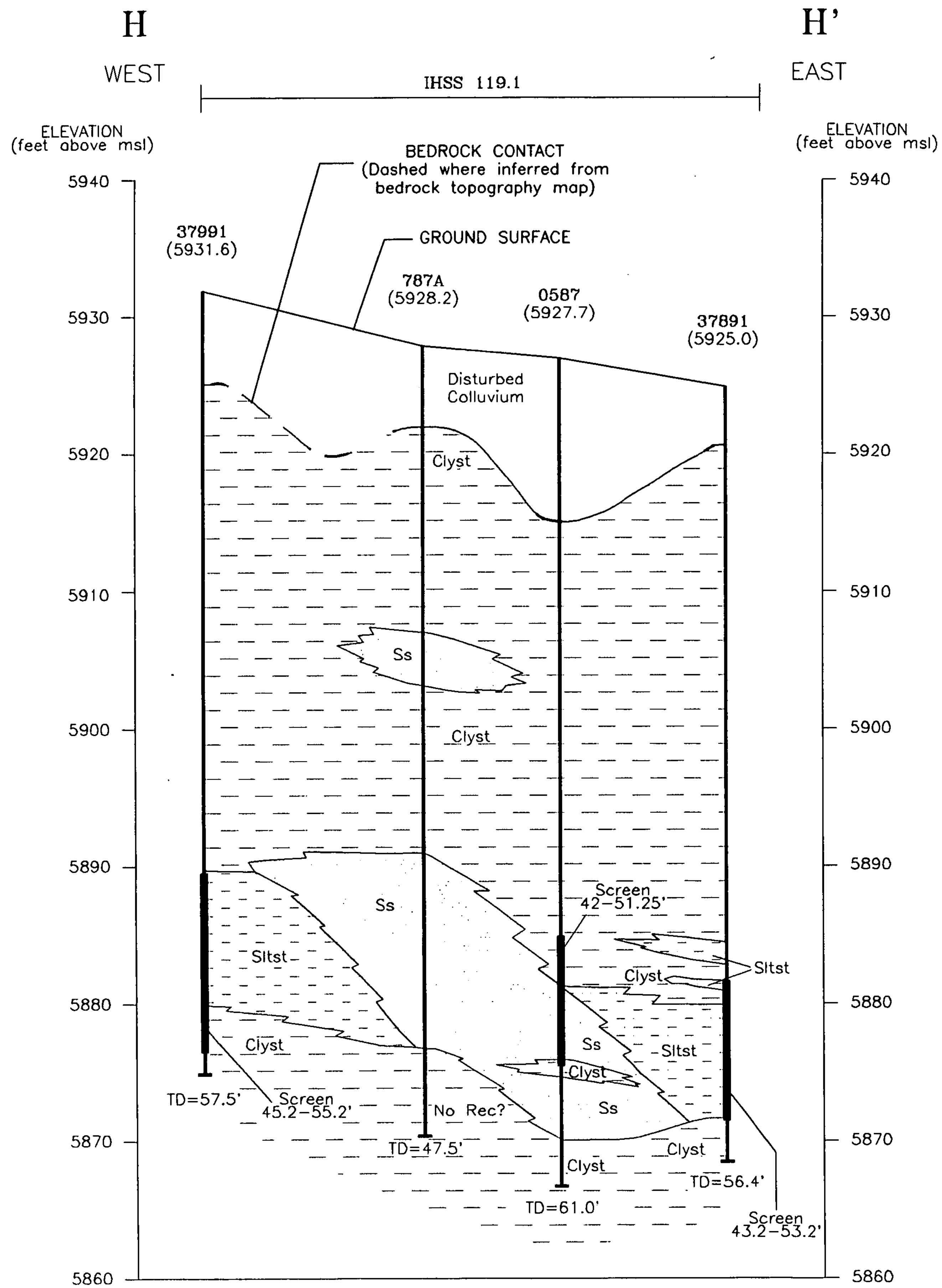
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

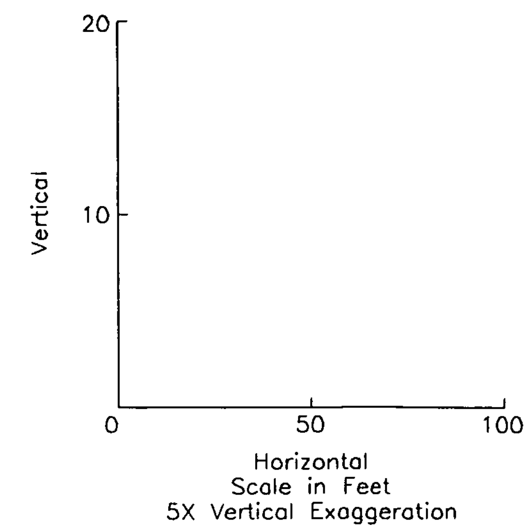
Bedrock Cross Section Location Map

Figure 3-18

OCTOBER 1993

R74047.pj-102993/200





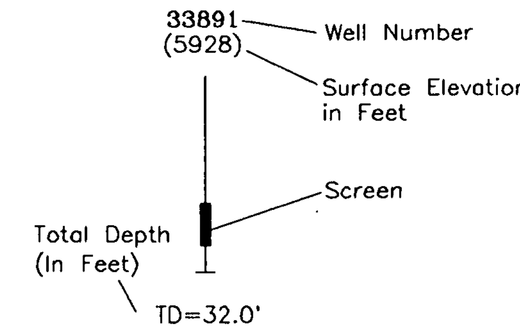
EXPLANATION

Disturbed Colluvium

Clyst – Claystone

Ss – Sandstone

Sltst – Siltstone



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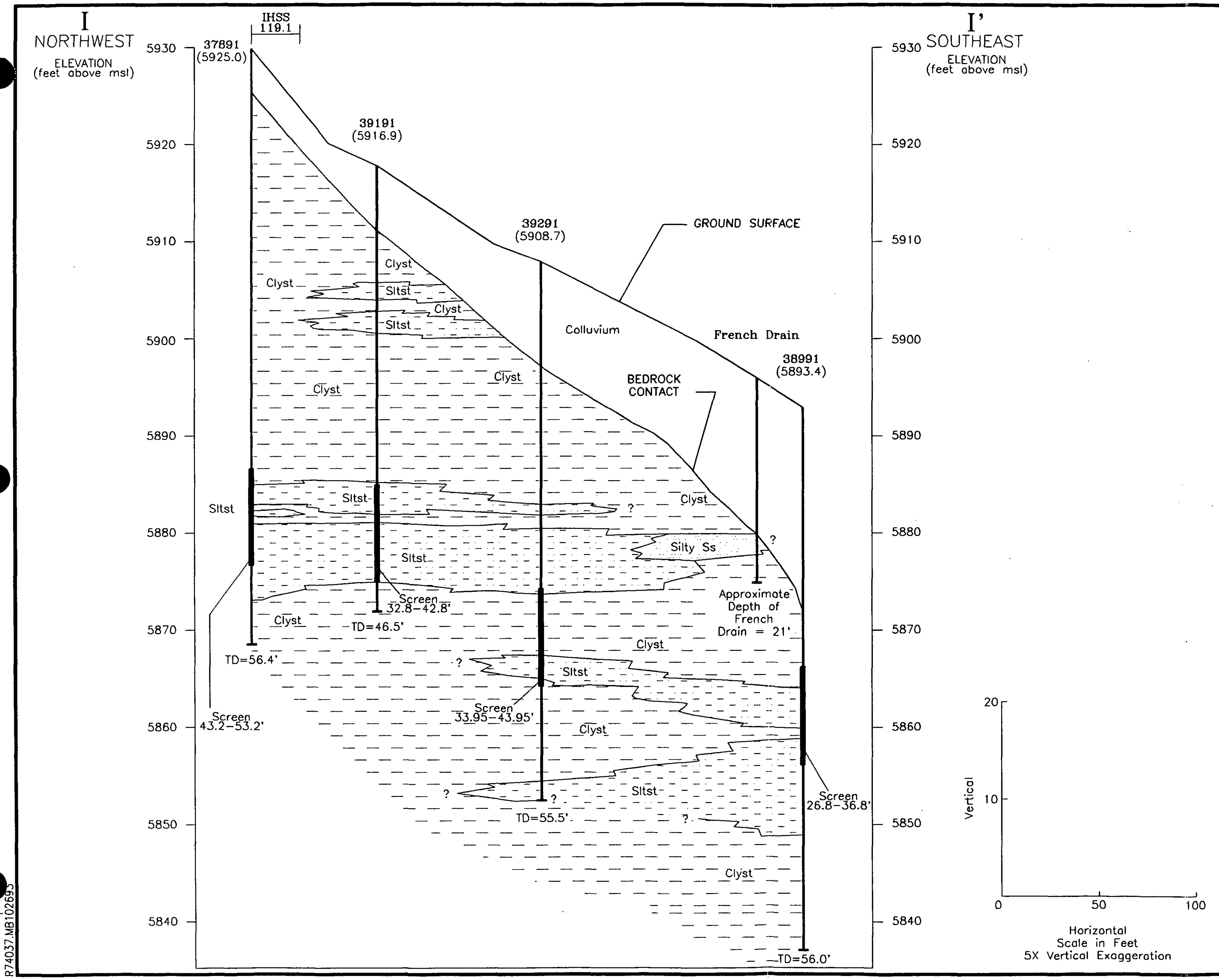
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Bedrock Cross Section
H–H'

Figure 3-19

REV. JANUARY 1994
OCTOBER 1992

R74036.MB01069



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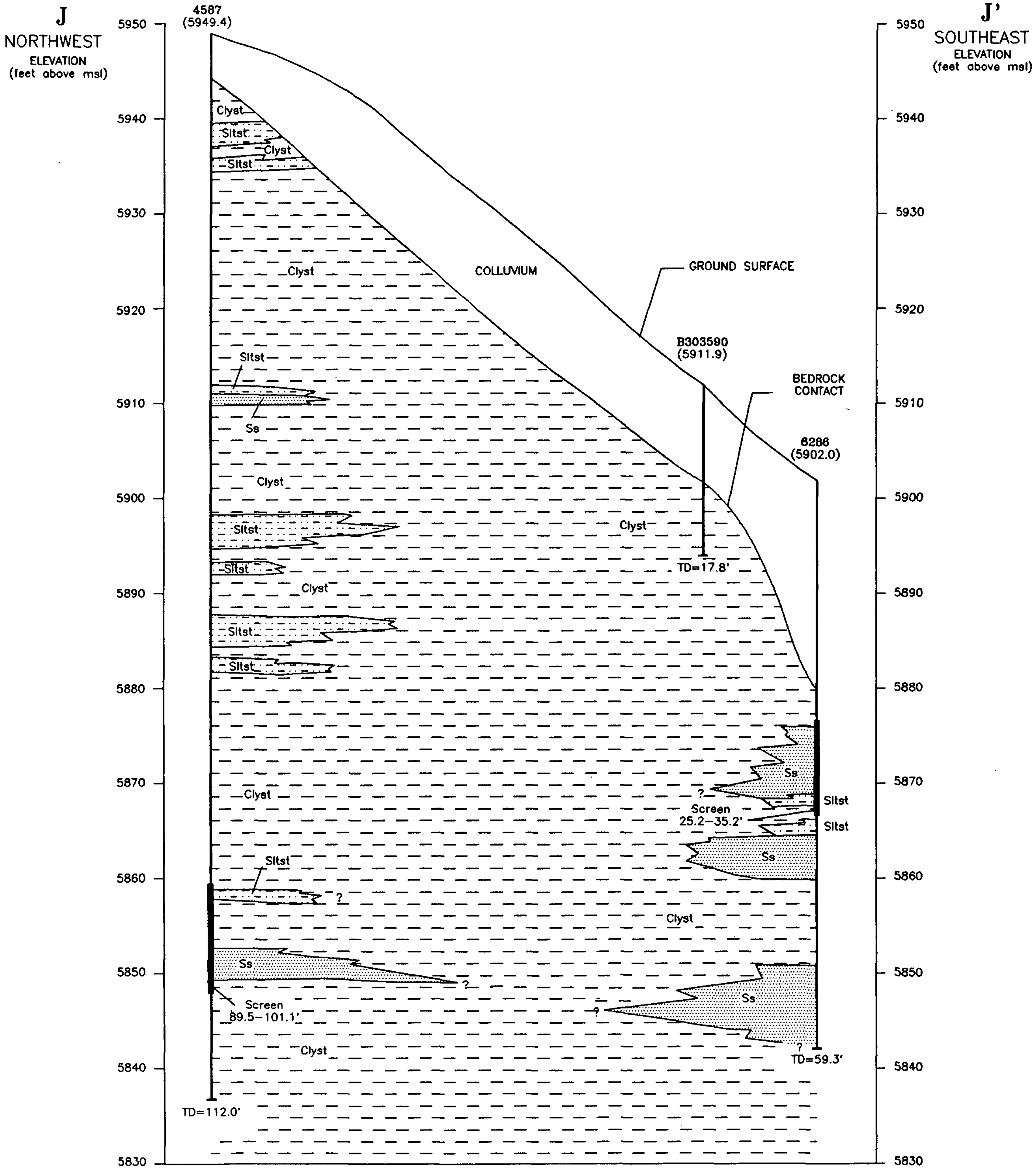
Rocky Flats Plant, Golden, Colorado

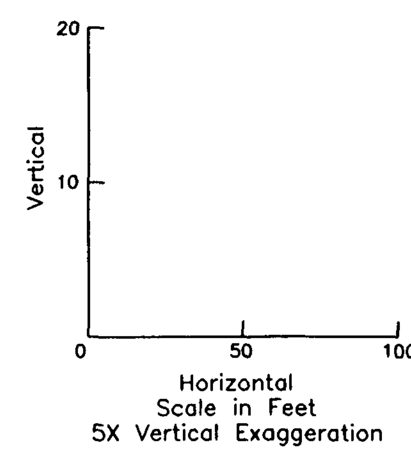
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Bedrock Cross Section
I–I'

Figure 3–20

REV. OCTOBER 1993
OCTOBER 1992





EXPLANATION

Clyst – Claystone

Ss – Sandstone

Sltst – Siltstone

33891 Well Number
(5928) Surface Elevation in Feet
Screen
Total Depth (In Feet)
TD=32.0'

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Rocky Flats Plant, Golden, Colorado

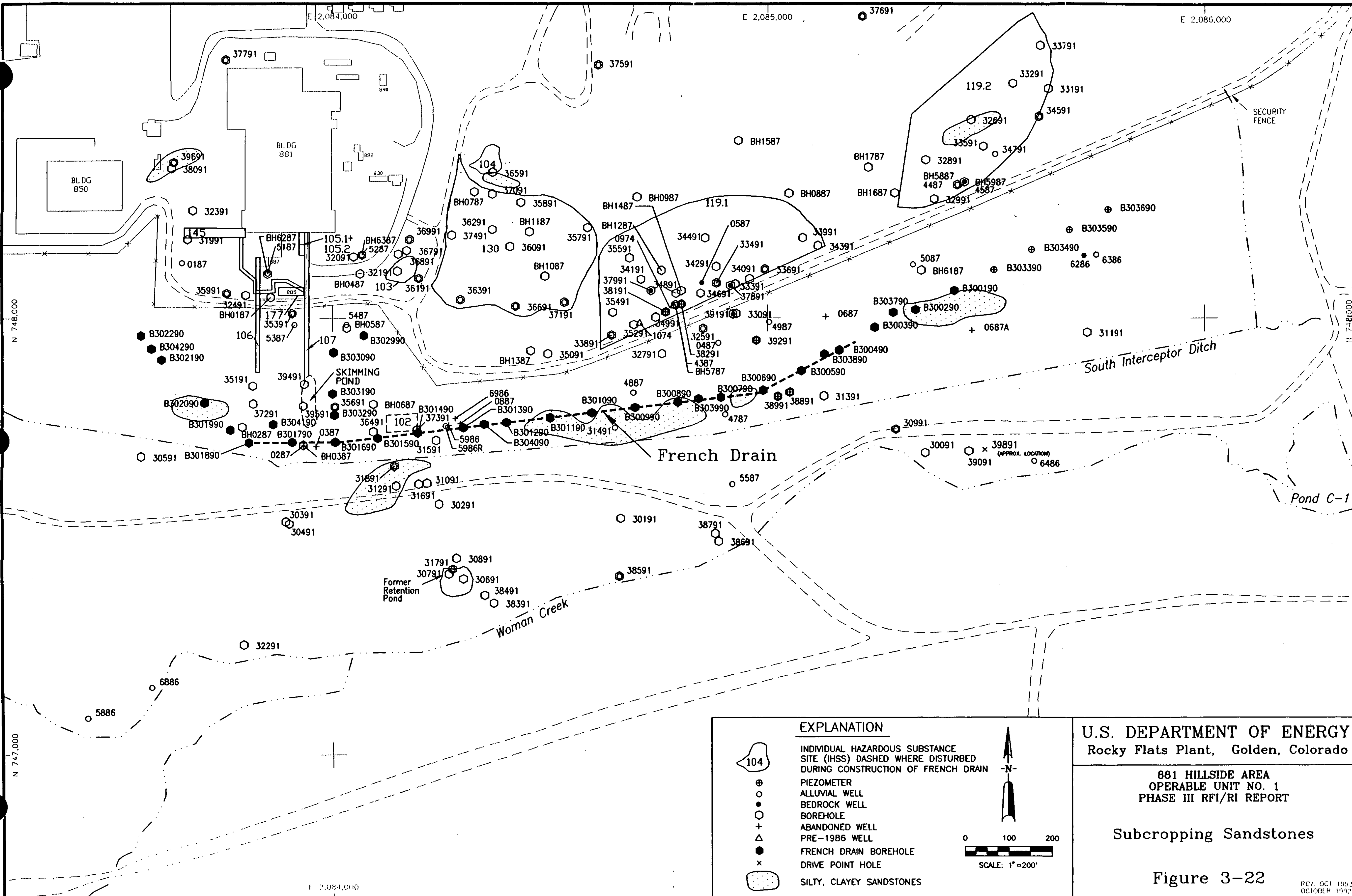
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Bedrock Cross Section
J–J'

Figure 3-21

REV. APRIL 1993
OCTOBER 1992

R74038.MB0712



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

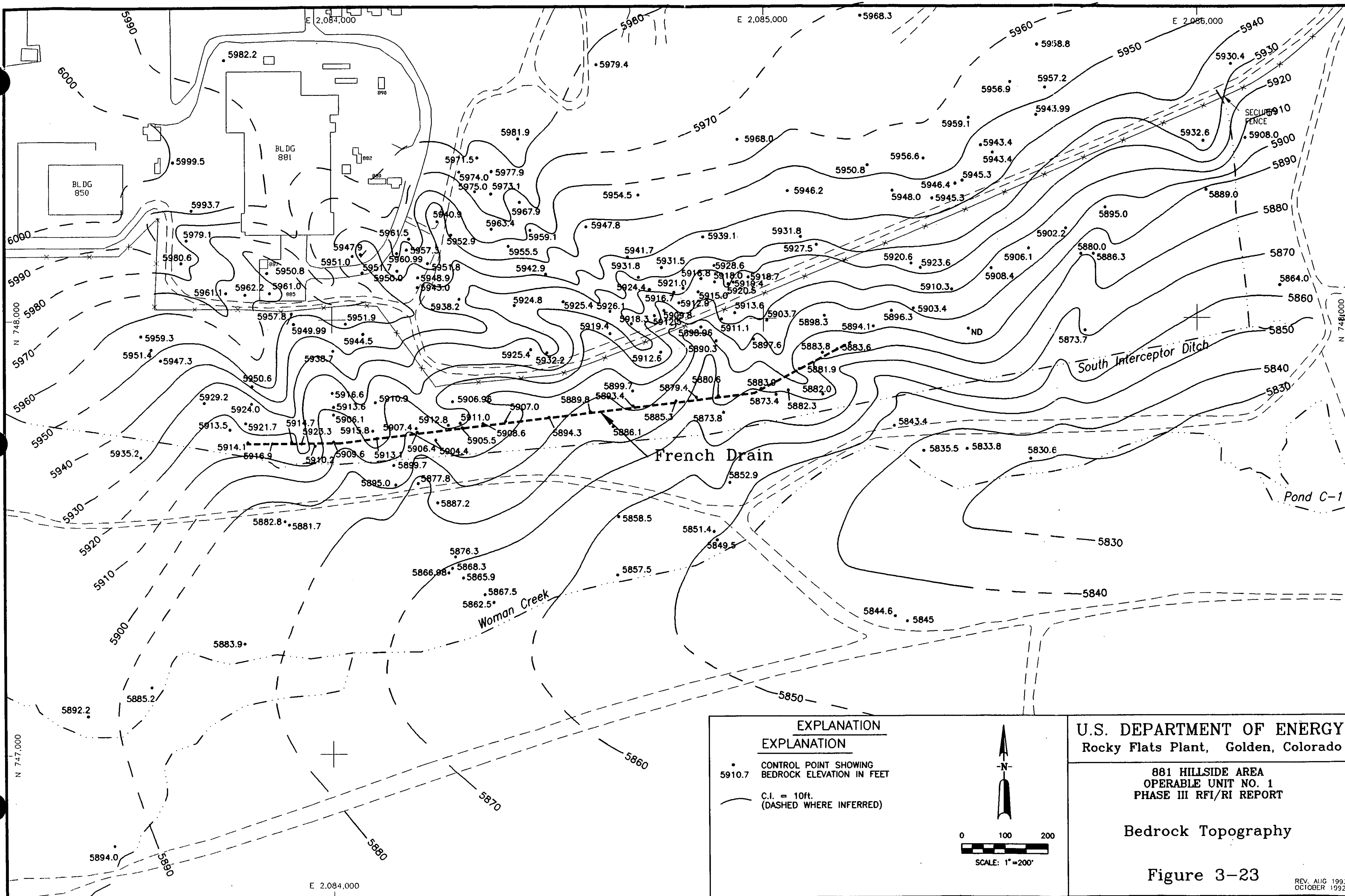
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Subcropping Sandstones

Figure 3-22

REV. OCT 1993
OCTOBER 1992

R74009.pj-102093/200



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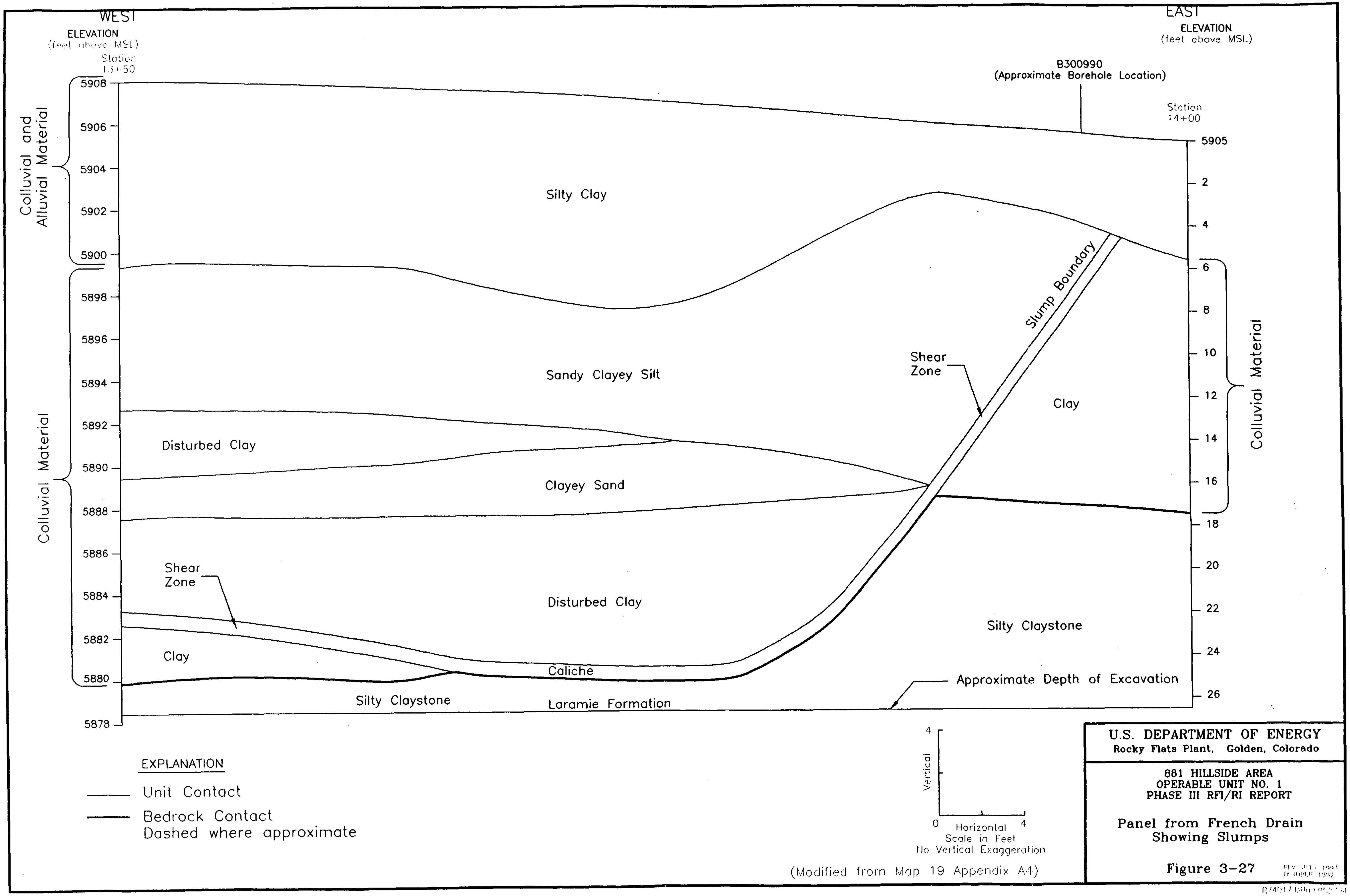
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Bedrock Topography

Figure 3-23

REV. AUG 1993
OCTOBER 1992

R74015.MB080593/200



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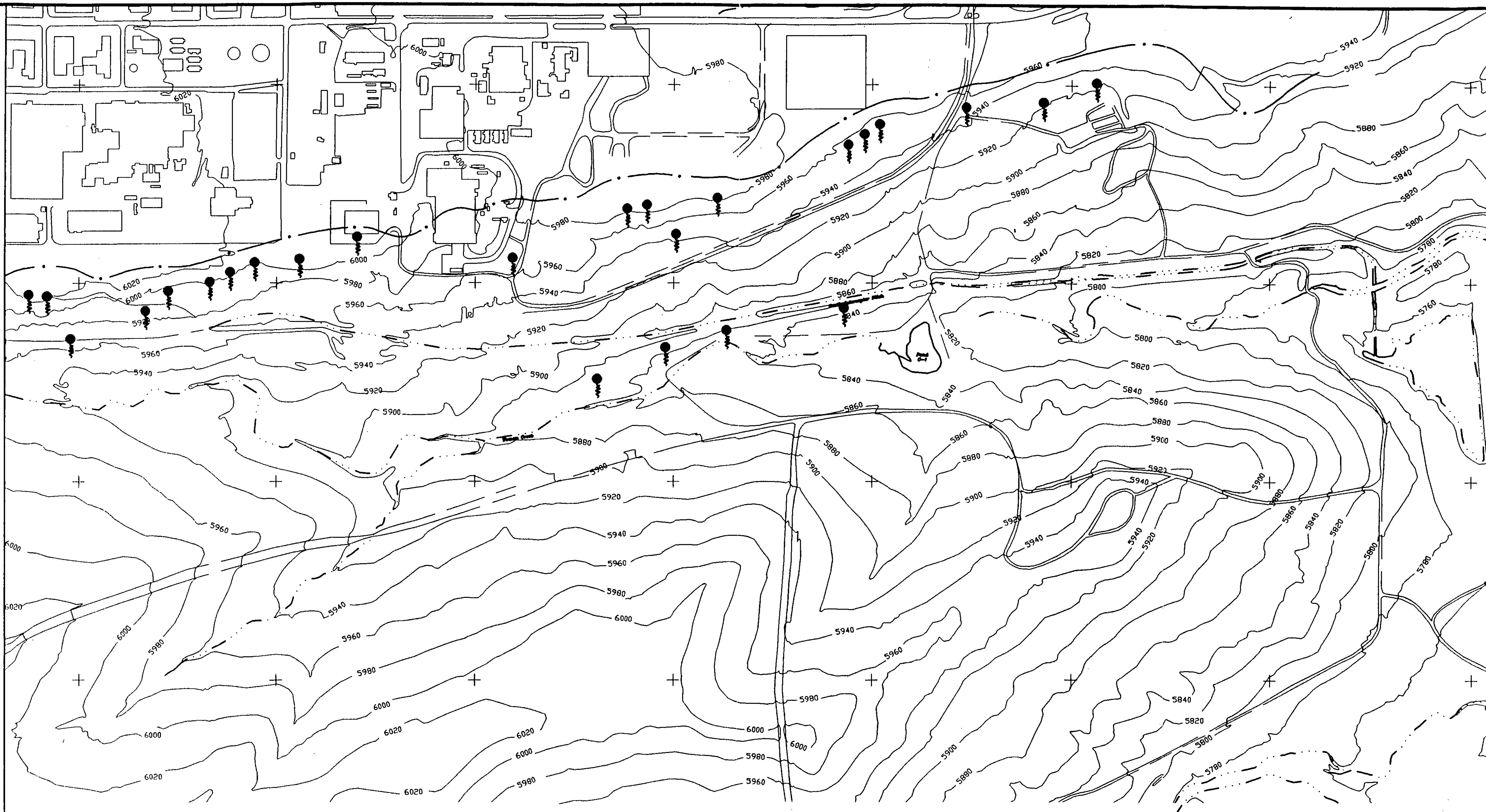
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Panel from French Drain Showing Slumps

Figure 3-27



EXPLANATION

Potential Seeps–Photointerpretation

Crest of 881 Hillside

-N-

0 250 500 750

SCALE IN FEET

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant, Golden, Colorado

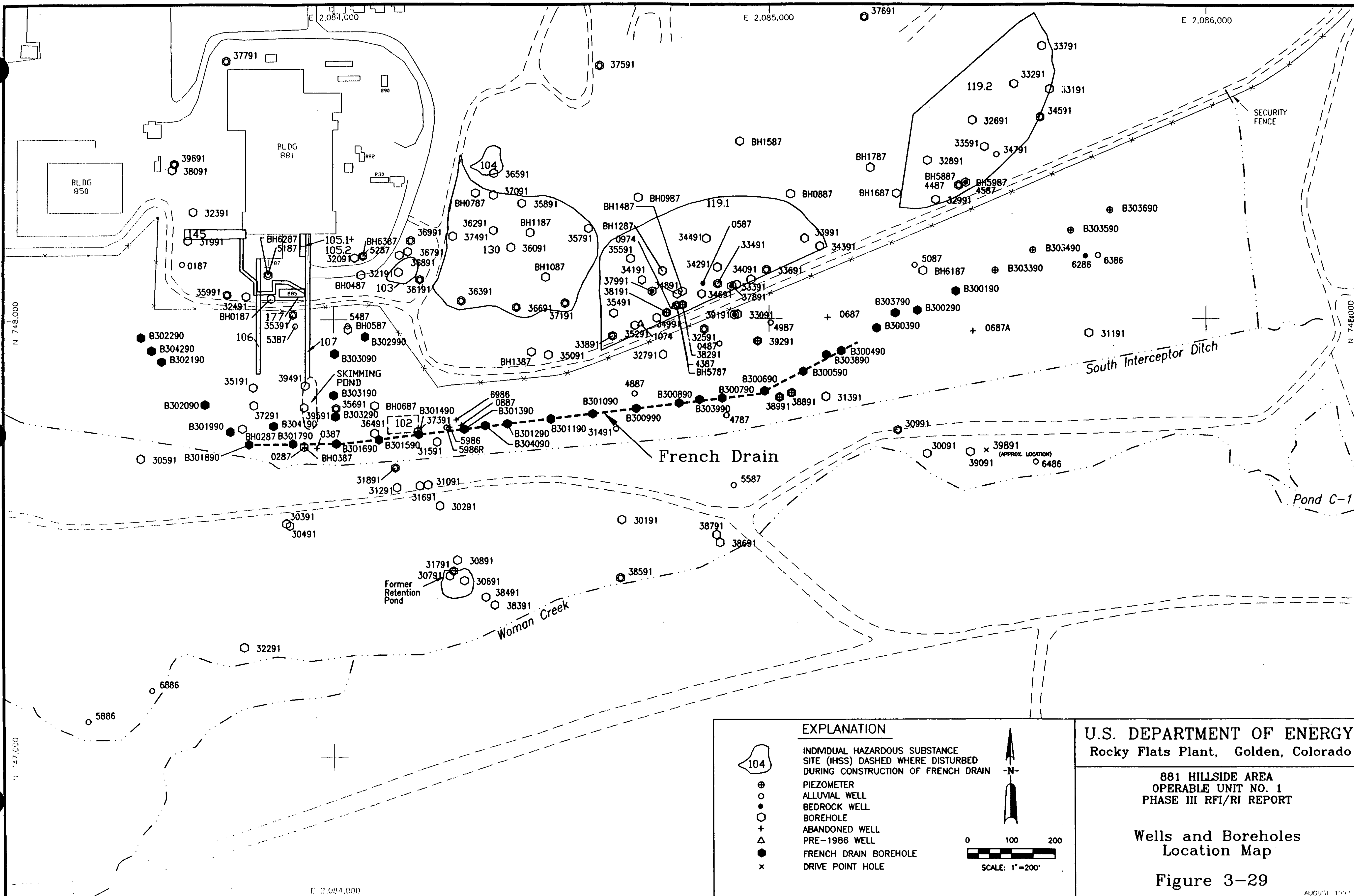
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Geomorphological Features – Photo Interpretation of Seeps (1951 Aerial Photographs)

Figure 3-28

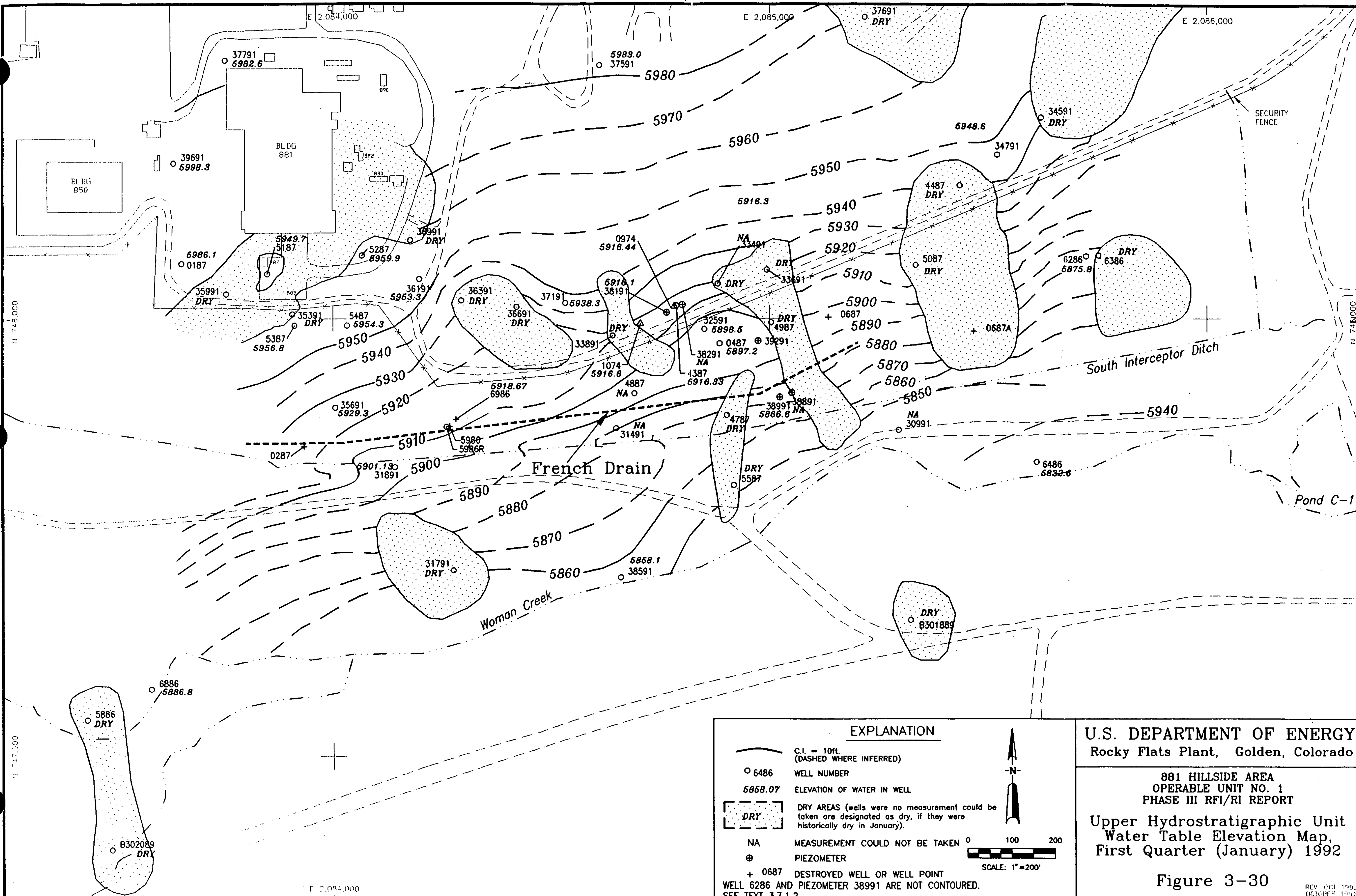
REV. FEB 1994
OCTOBER 1992

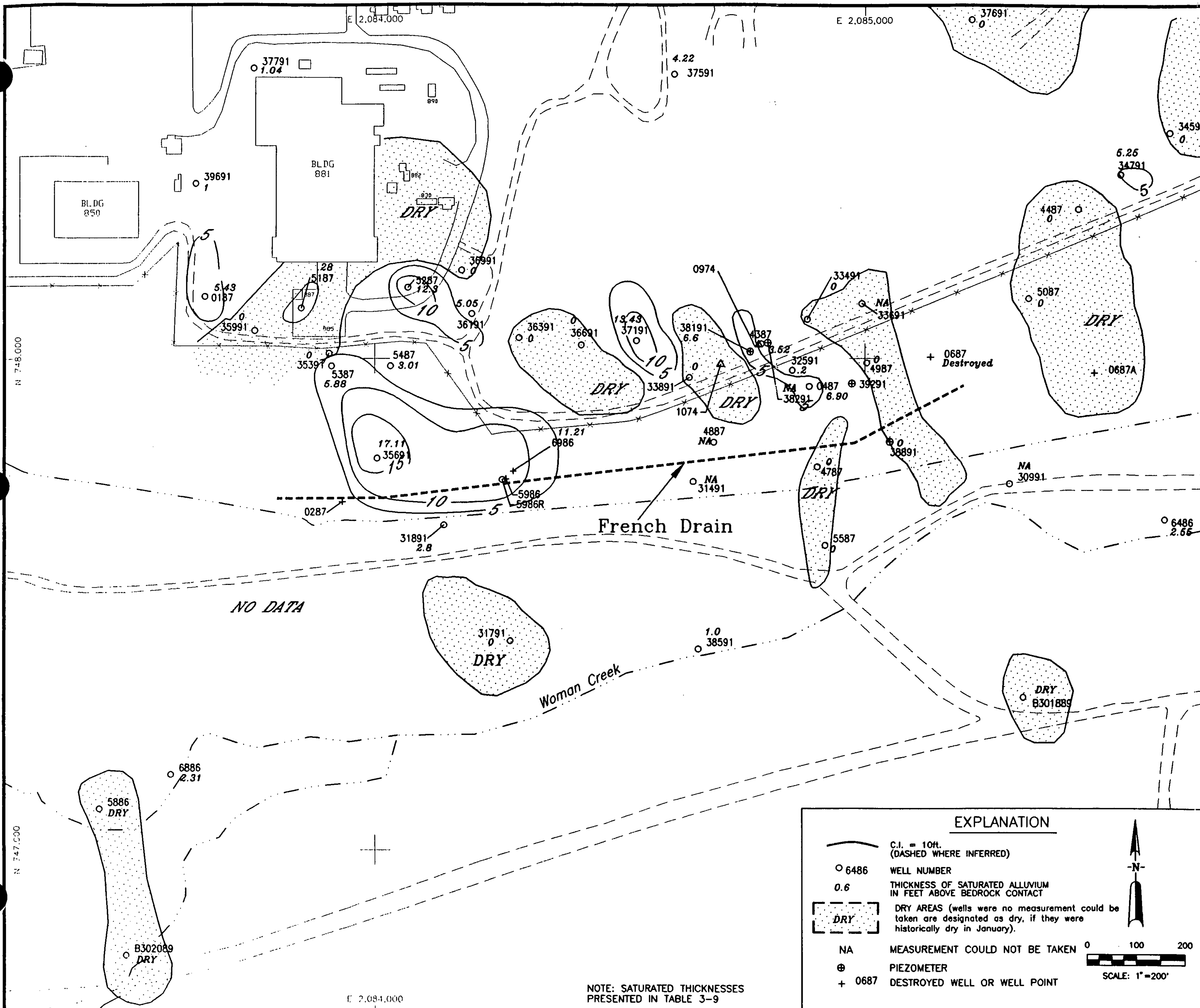
R74048.MBCWpj-052594/500



E 2,084,000
E 2,085,000
E 2,086,000
N 748,000
N 747,000
BLDG 881
BLDG 850
SECURITY FENCE
119.2
119.1
104
130
103
102
105.1
105.2
106
107
177
145
SKIMMING POND
South Interceptor Ditch
French Drain
Woman Creek
Former Retention Pond
Pond C-1
EXPLANATION
INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
PIEZOMETER
ALLUVIAL WELL
BEDROCK WELL
BOREHOLE
ABANDONED WELL
PRE-1986 WELL
FRENCH DRAIN BOREHOLE
DRIVE POINT HOLE
-N-
0 100 200
SCALE: 1" = 200'
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT
Wells and Boreholes Location Map
Figure 3-29

R74010.pj


E 2,084,000
E 2,085,000
E 2,086,000
N 748,000
BLDG 881
BLDG 850
37791
5982.6
39691
5998.3
5983.0
37591
37691
DRY
34591
DRY
6948.6
34791
4487
DRY
5087
DRY
6286
5875.8
6386
DRY
0687A
5916.3
0974
5916.44
NA
33491
DRY
33691
DRY
5916.1
38191
37191
5938.3
36391
DRY
36691
DRY
33891
DRY
1074
5916.8
38291
NA
4387
5916.33
32591
5898.5
0487
5897.2
39291
DRY
4987
0687
4887
NA
38991
5866.6
38891
NA
4787
DRY
NA
30991
NA
31491
5918.67
6986
5986
5986R
35691
5929.3
0287
5901.13
31891
DRY
5587
6486
5832.6
5949.7
5187
5287
5959.9
36991
DRY
36191
5953.3
6986.1
0187
35991
DRY
35391
DRY
5487
5954.3
5387
5956.8
31791
DRY
5858.1
38591
DRY
B301889
6886
5886.8
5886
DRY
B302089
DRY
5980
5970
5960
5950
5940
5930
5920
5910
5900
5890
5880
5870
5860
5850
French Drain
South Interceptor Ditch
Woman Creek
Pond C-1
SECURITY FENCE
EXPLANATION
C.I. = 10ft. (DASHED WHERE INFERRED)
6486 WELL NUMBER
5858.07 ELEVATION OF WATER IN WELL
DRY DRY AREAS (wells were no measurement could be taken are designated as dry, if they were historically dry in January).
NA MEASUREMENT COULD NOT BE TAKEN
PIEZOMETER
+ 0687 DESTROYED WELL OR WELL POINT
WELL 6286 AND PIEZOMETER 38991 ARE NOT CONTOURED. SEE TEXT 3.7.1.2.
N
0 100 200
SCALE: 1"=200'
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT
Upper Hydrostratigraphic Unit Water Table Elevation Map, First Quarter (January) 1992
Figure 3-30



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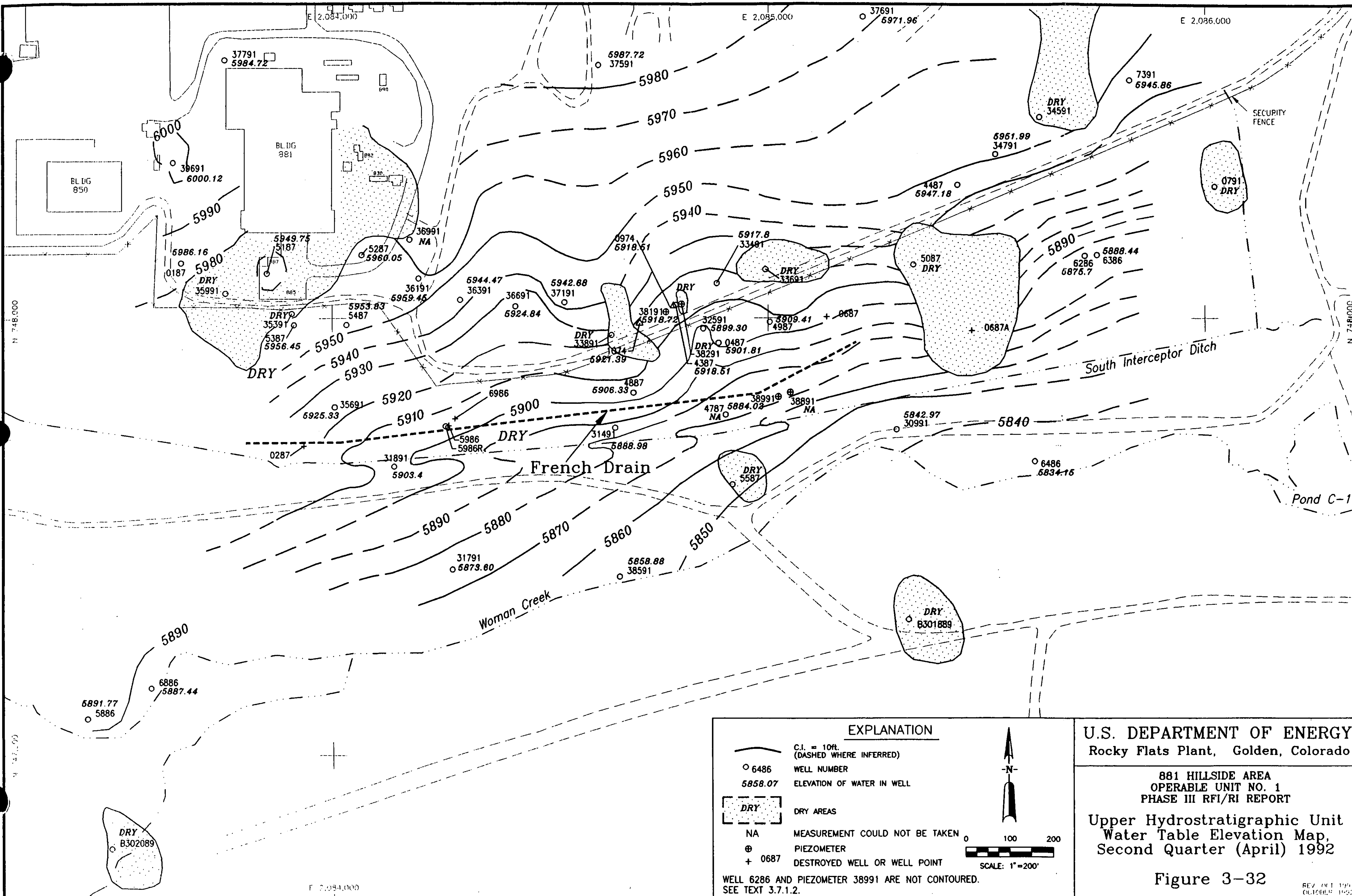
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Upper Hydrostratigraphic Unit Saturated Thickness Map, First Quarter (January) 1992

Figure 3-31

REV. OCT 1993
OCTOBER 1992



EXPLANATION

C.I. = 10ft. (DASHED WHERE INFERRED)

○ 6486 WELL NUMBER

5858.07 ELEVATION OF WATER IN WELL

DRY — DRY AREAS

NA — MEASUREMENT COULD NOT BE TAKEN

⊕ PIEZOMETER

+ 0687 DESTROYED WELL OR WELL POINT

N

0 100 200

SCALE: 1" = 200'

WELL 6286 AND PIEZOMETER 38991 ARE NOT CONTOURED. SEE TEXT 3.7.1.2.

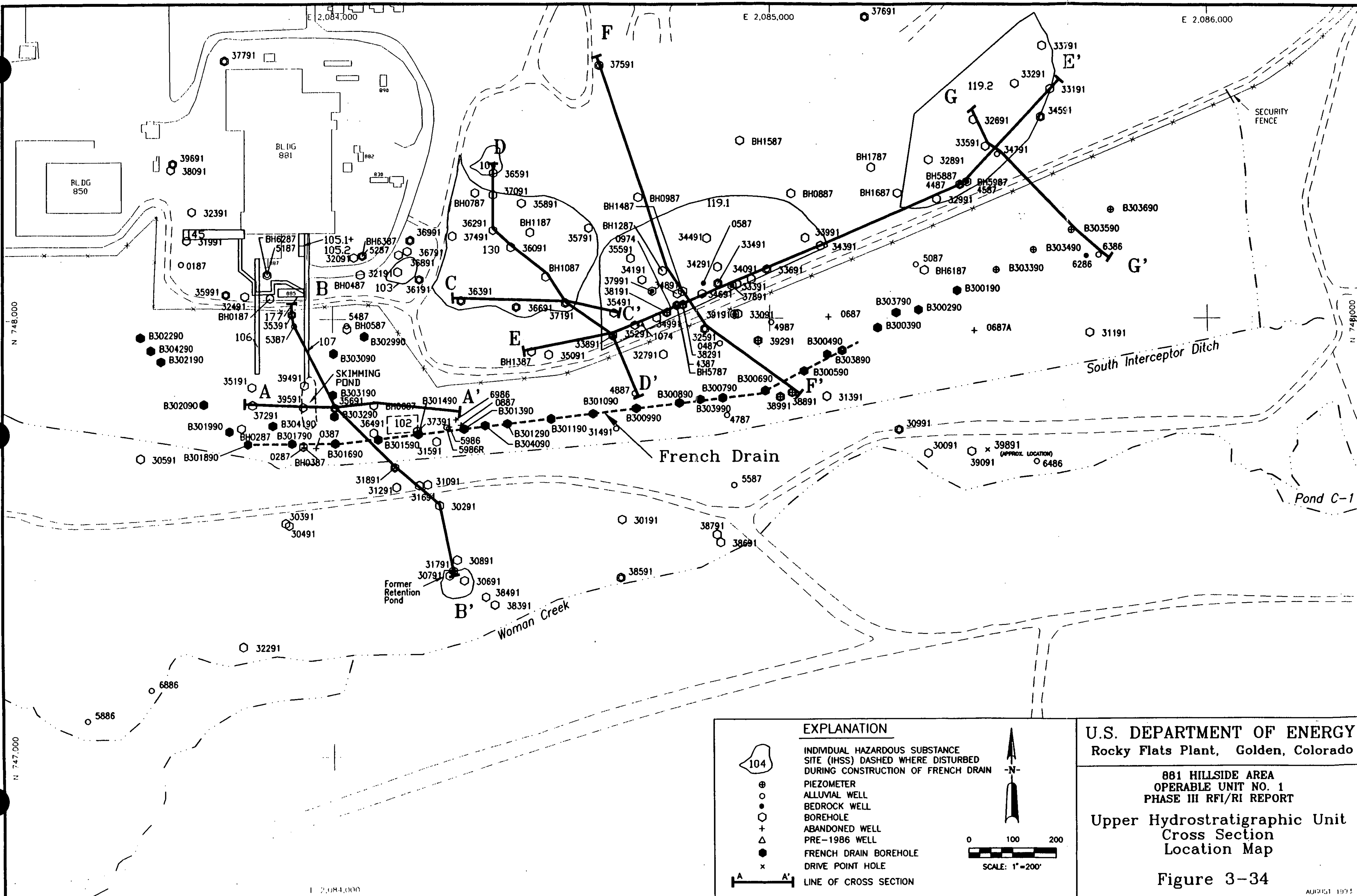
U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant, Golden, Colorado

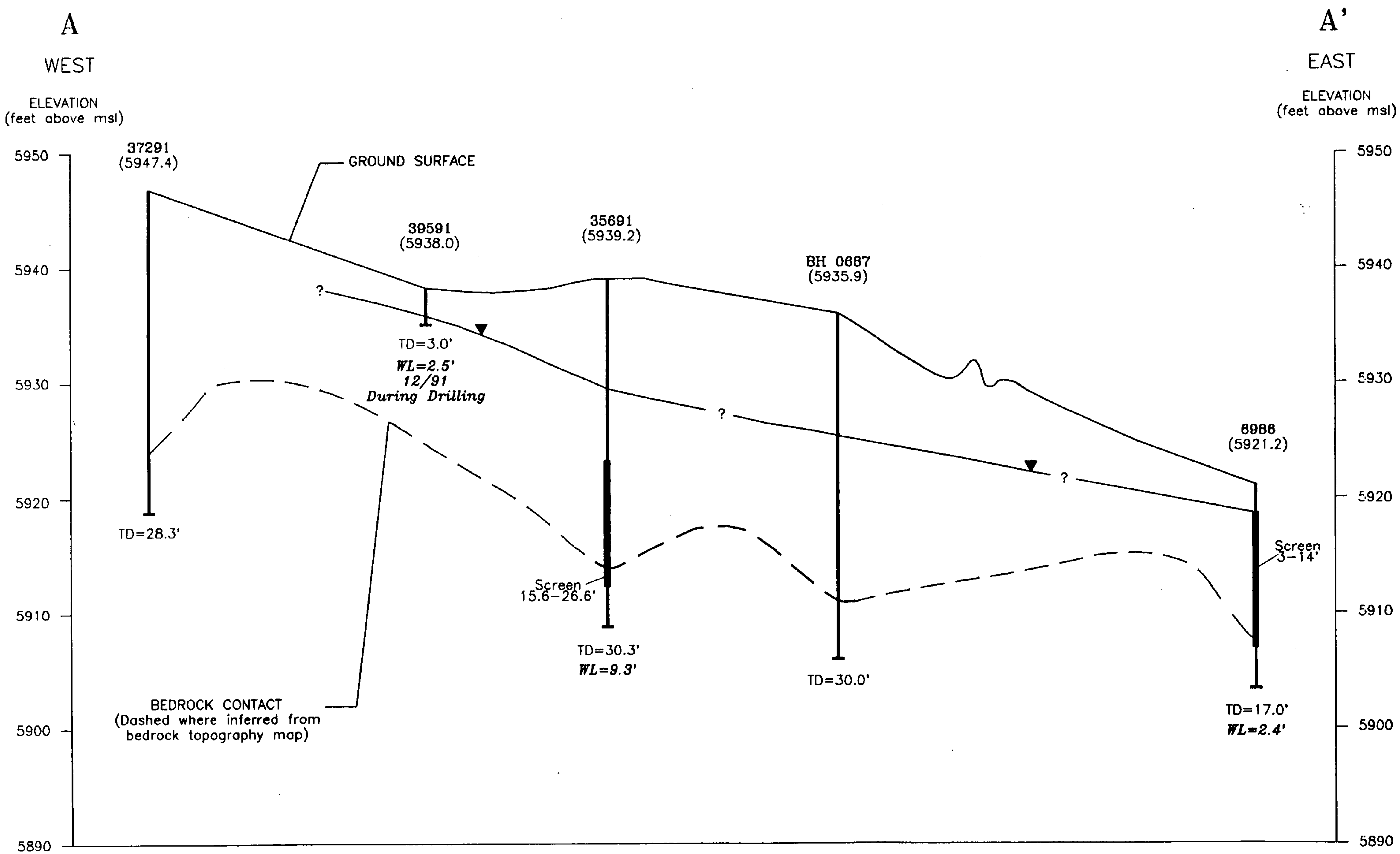
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

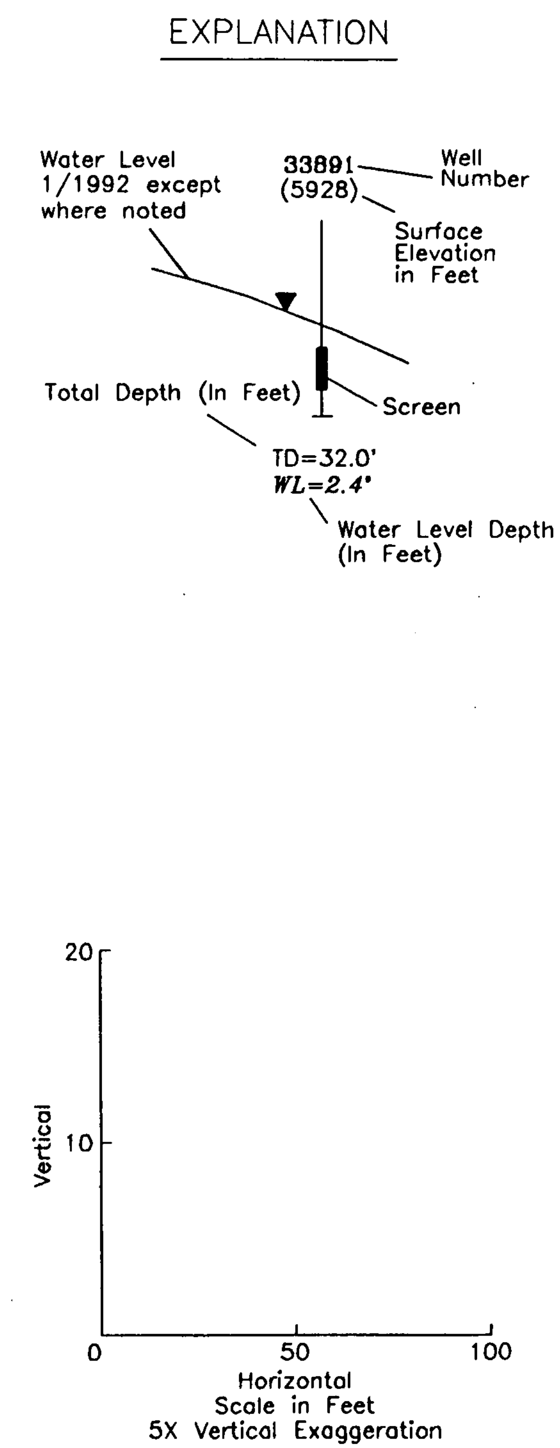
Upper Hydrostratigraphic Unit Water Table Elevation Map, Second Quarter (April) 1992

Figure 3-32



E 2,084,000
E 2,085,000
E 2,086,000
N 748,000
N 747,000
BLDG 881
BLDG 850
SKIMMING POND
Former Retention Pond
French Drain
South Interceptor Ditch
Woman Creek
Pond C-1
SECURITY FENCE
A
A'
B
B'
C
C'
D
D'
E
E'
F
F'
G
G'
EXPLANATION
INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
PIEZOMETER
ALLUVIAL WELL
BEDROCK WELL
BOREHOLE
ABANDONED WELL
PRE-1986 WELL
FRENCH DRAIN BOREHOLE
DRIVE POINT HOLE
LINE OF CROSS SECTION
-N-
0 100 200
SCALE: 1"=200'
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT
Upper Hydrostratigraphic Unit Cross Section Location Map
Figure 3-34
AUGUST 1993
R74013.pj-083093/200





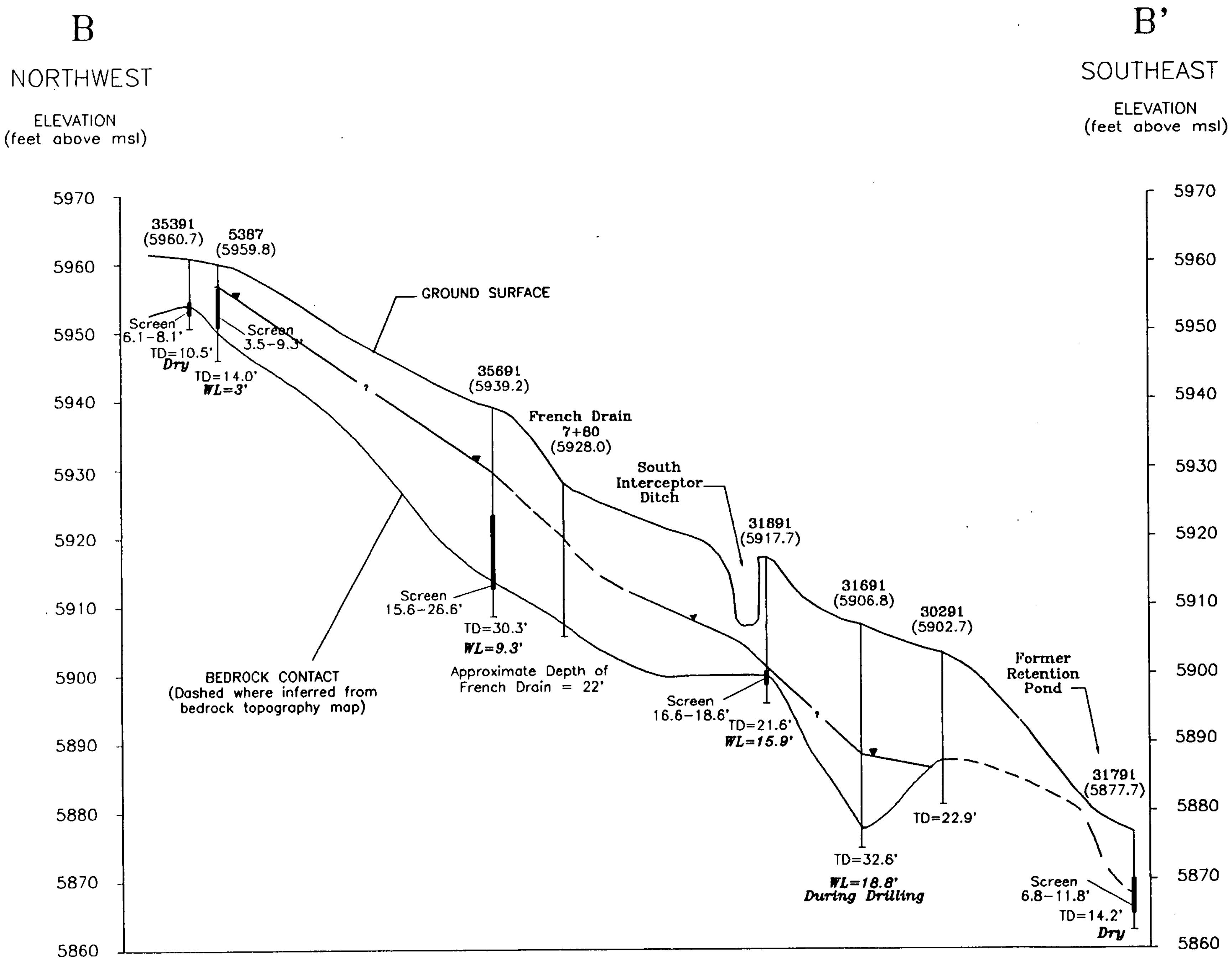
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

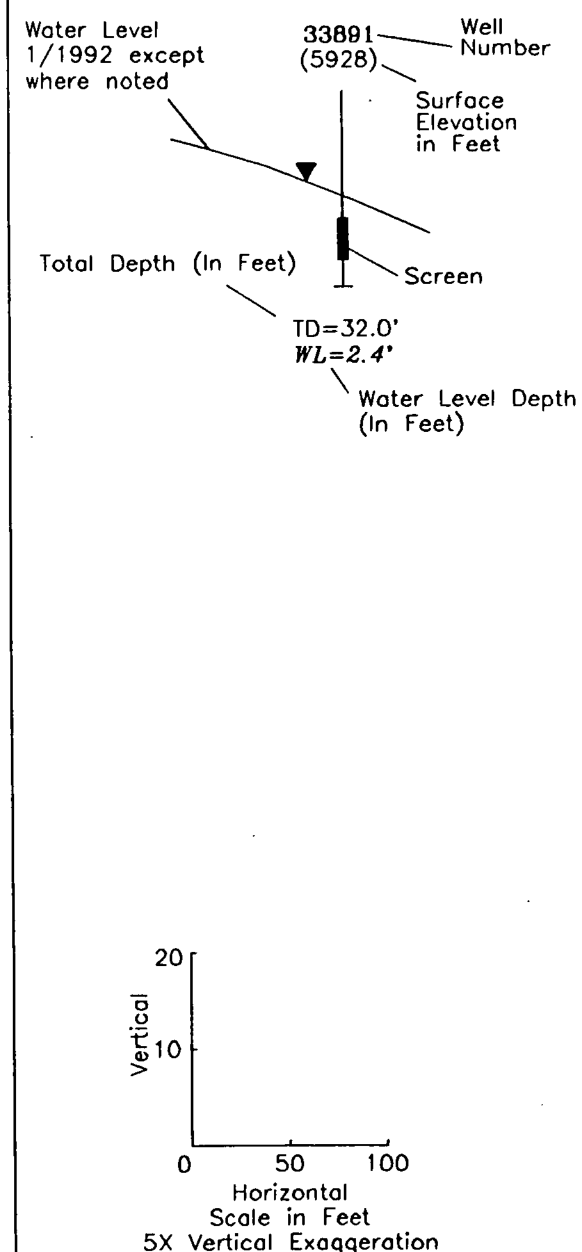
Upper Hydrostratigraphic Unit
Cross Section A–A'
Figure 3–35

REV. AUG 1993
OCTOBER 1992

R74045.MBpi-082693



EXPLANATION



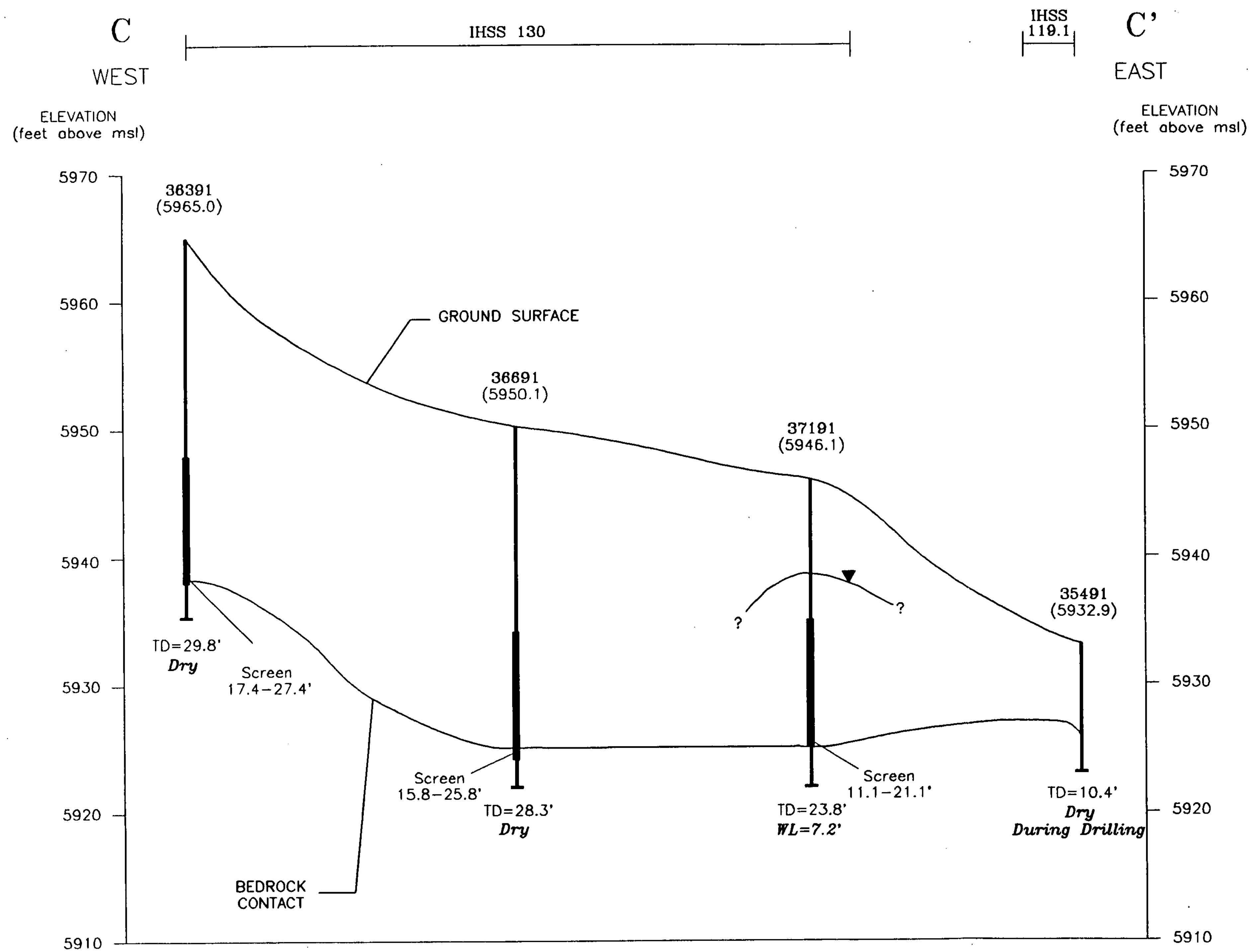
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

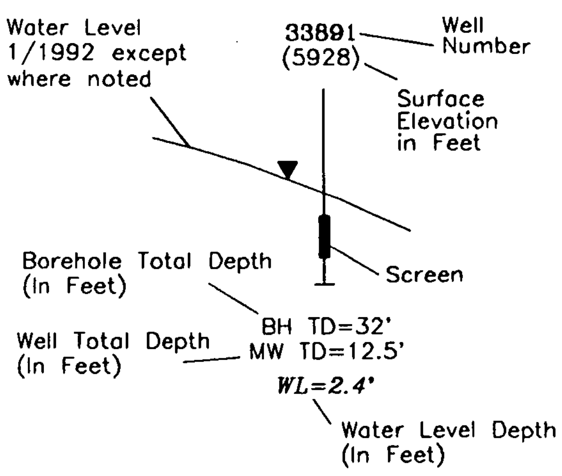
Upper Hydrostratigraphic Unit
Cross Section B-B'
Figure 3-36

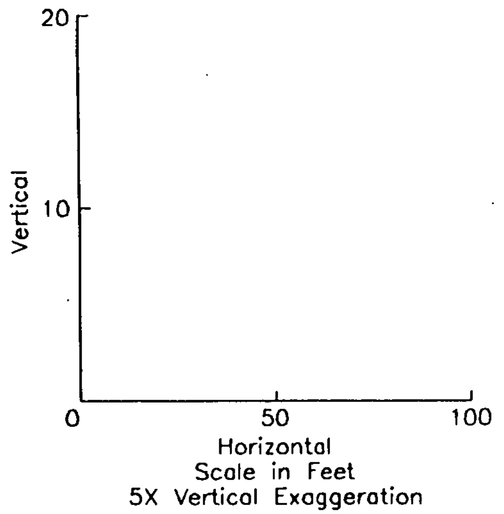
REV. OCTOBER 1993
OCTOBER 1992

R74025.MBMB102



EXPLANATION





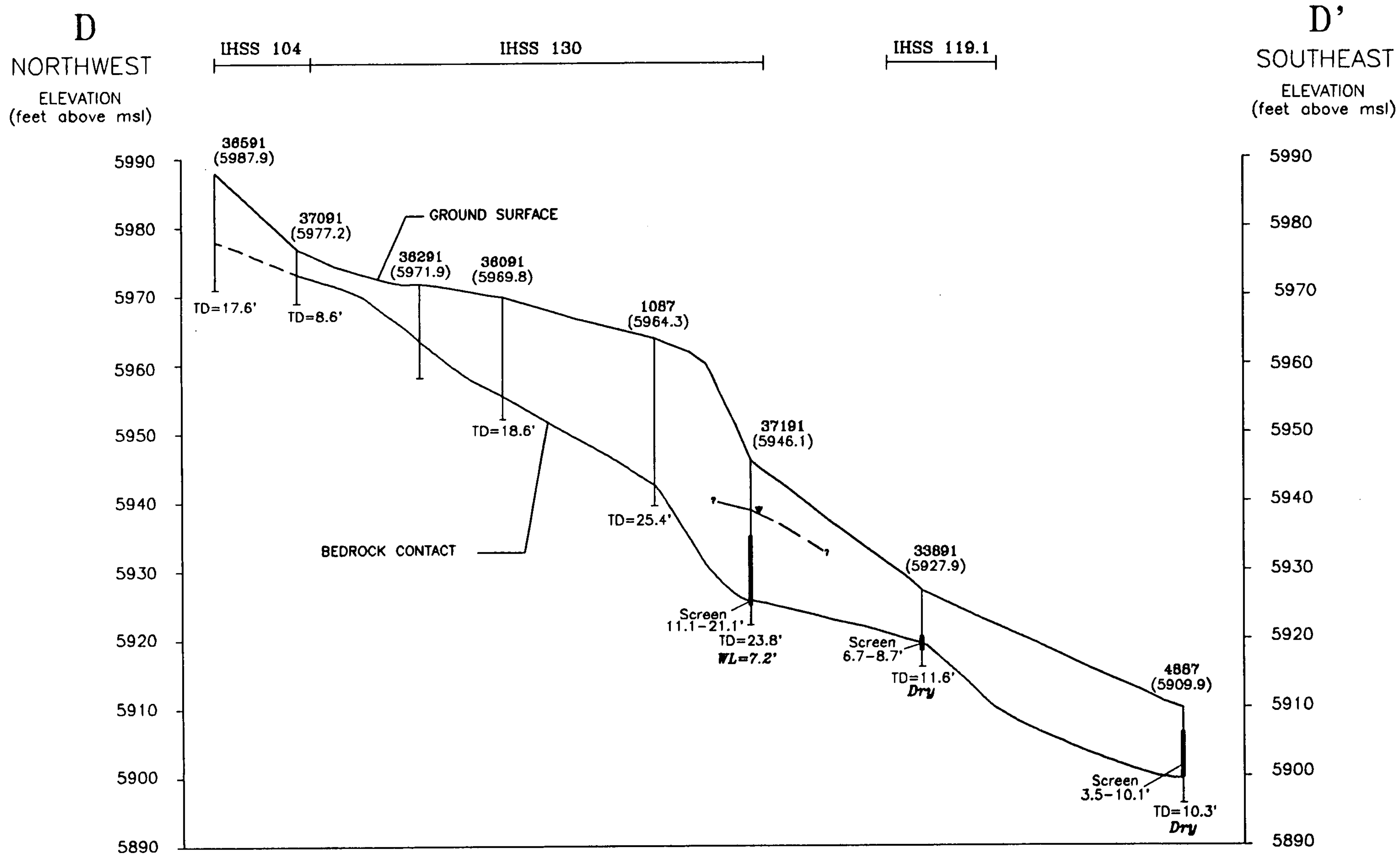
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

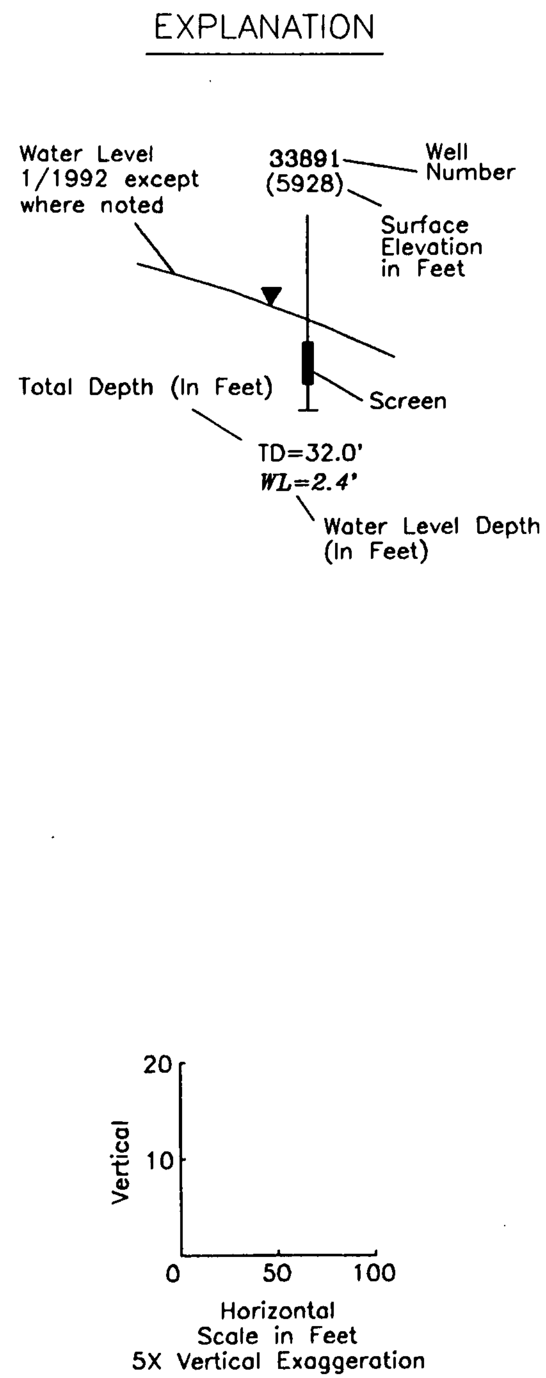
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Upper Hydrostratigraphic Unit
Cross Section C-C'
Figure 3-37

REV. OCTOBER 1993
OCTOBER 1992

R74035.MBMB102193





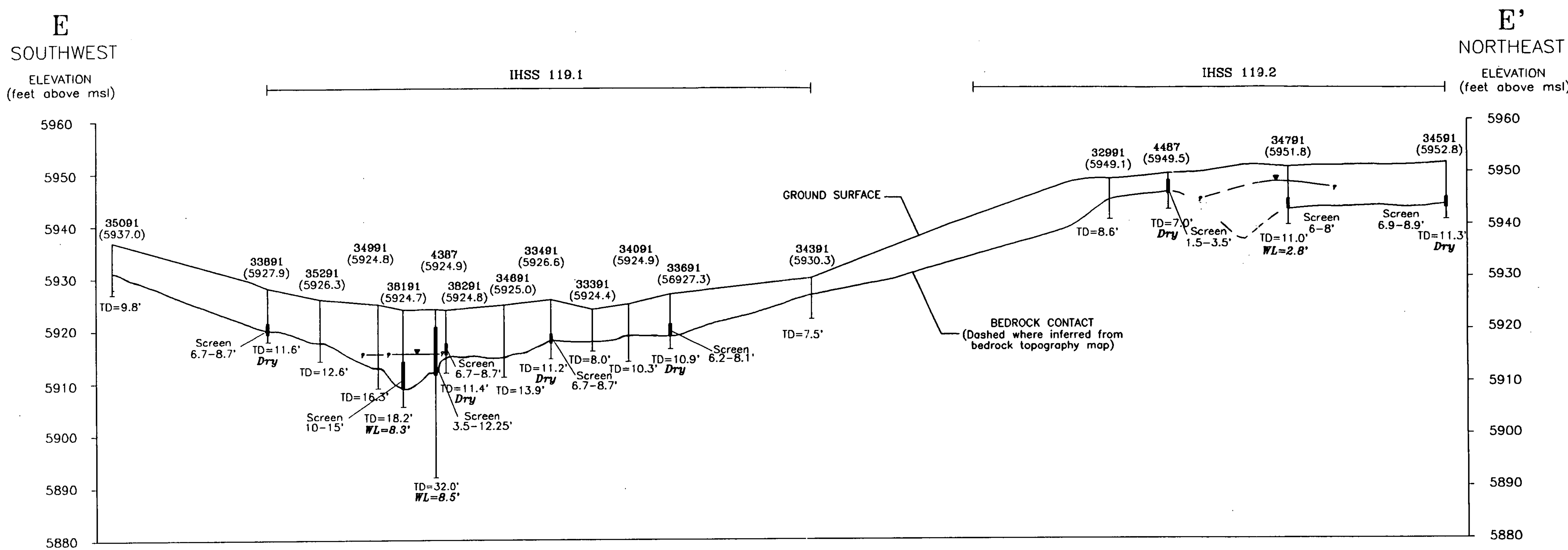
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

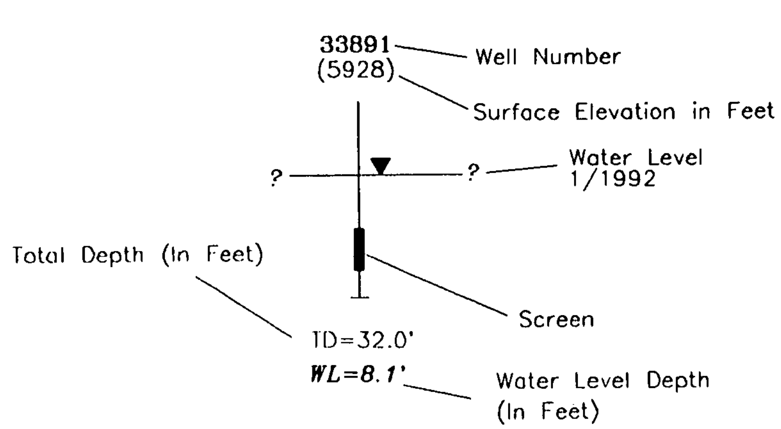
Upper Hydrostratigraphic Unit
Cross Section D-D'
Figure 3-38

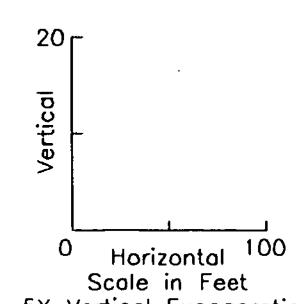
REV. AUG 1993
OCTOBER 1992

R74034.MBpj-082693



EXPLANATION





U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

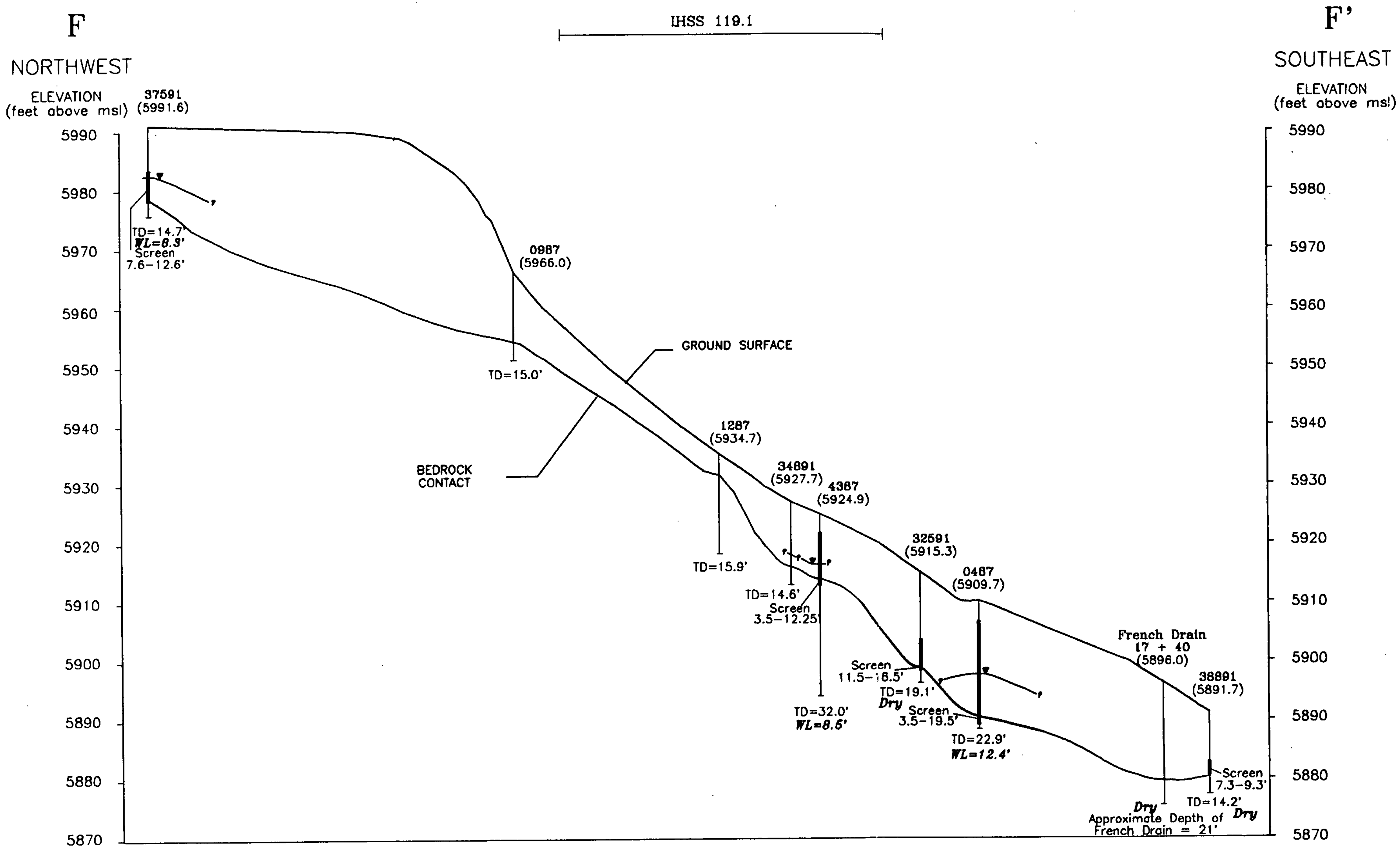
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

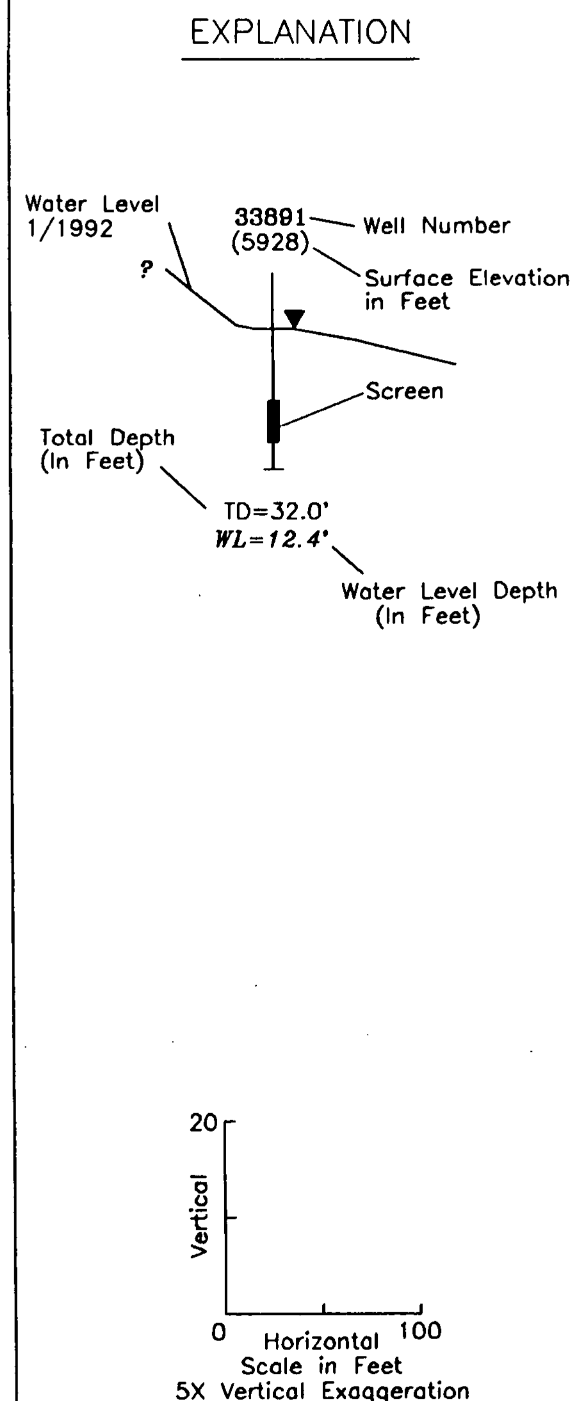
Upper Hydrostratigraphic Unit
Cross Section E-E'

Figure 3-39

REV. OCTOBER 1993
OCTOBER 1992

R74046.MBMB102193





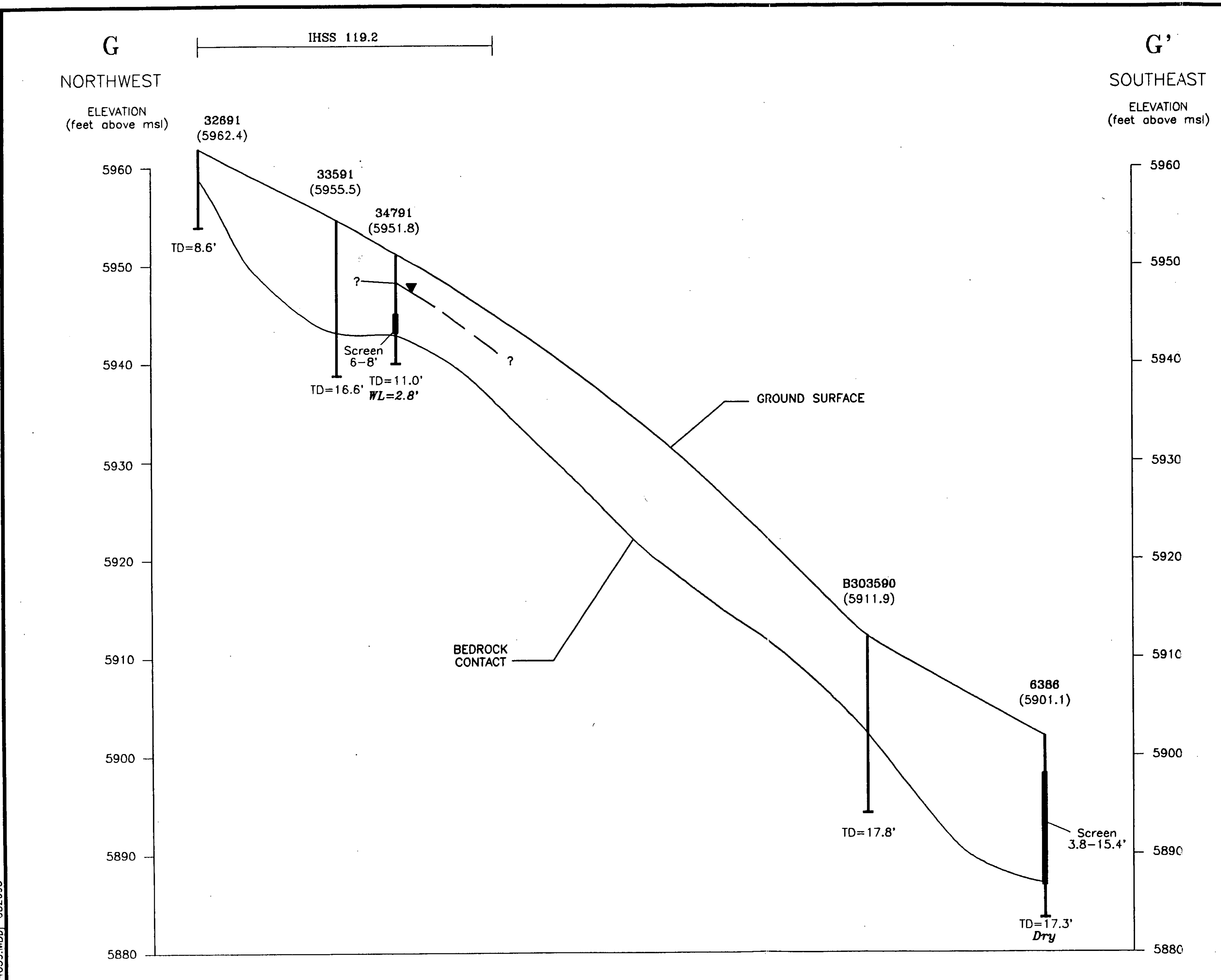
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Upper Hydrostratigraphic Unit
Cross Section F-F'
Figure 3-40

REV. AUG 1993
OCTOBER 1992

R74040.MBpi-082693



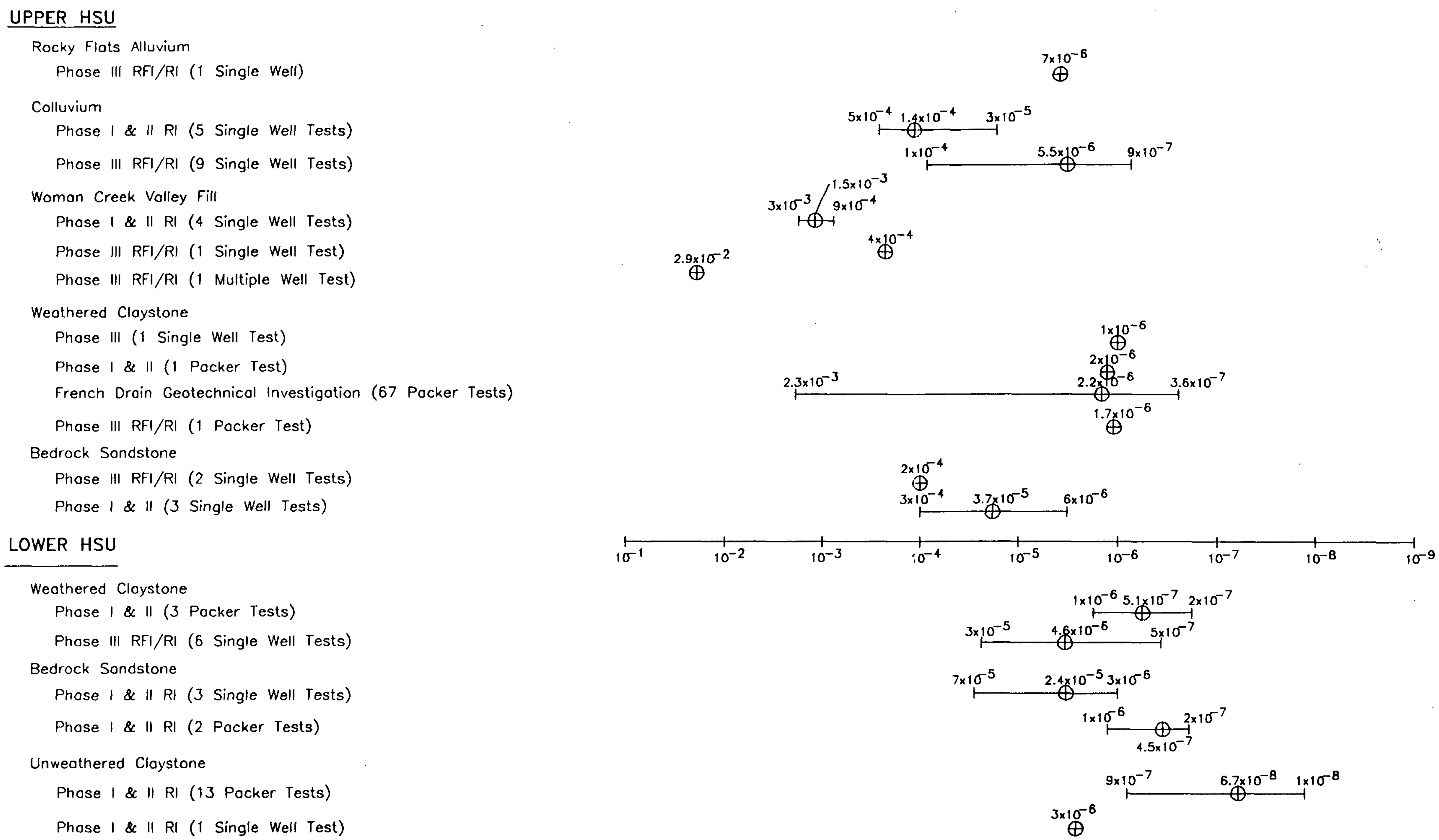
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Upper Hydrostratigraphic Unit
Cross Section G-G'
Figure 3-41

REV. AUG 1993
OCTOBER 1992

R74039.MBpj-082693



NOTES:

All Hydraulic Conductivity Values in cm/sec presented in Tables 3-6, 3-7, 3-8, 3-13, and 3-14

⊕ Geometric Mean of Range Presented

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

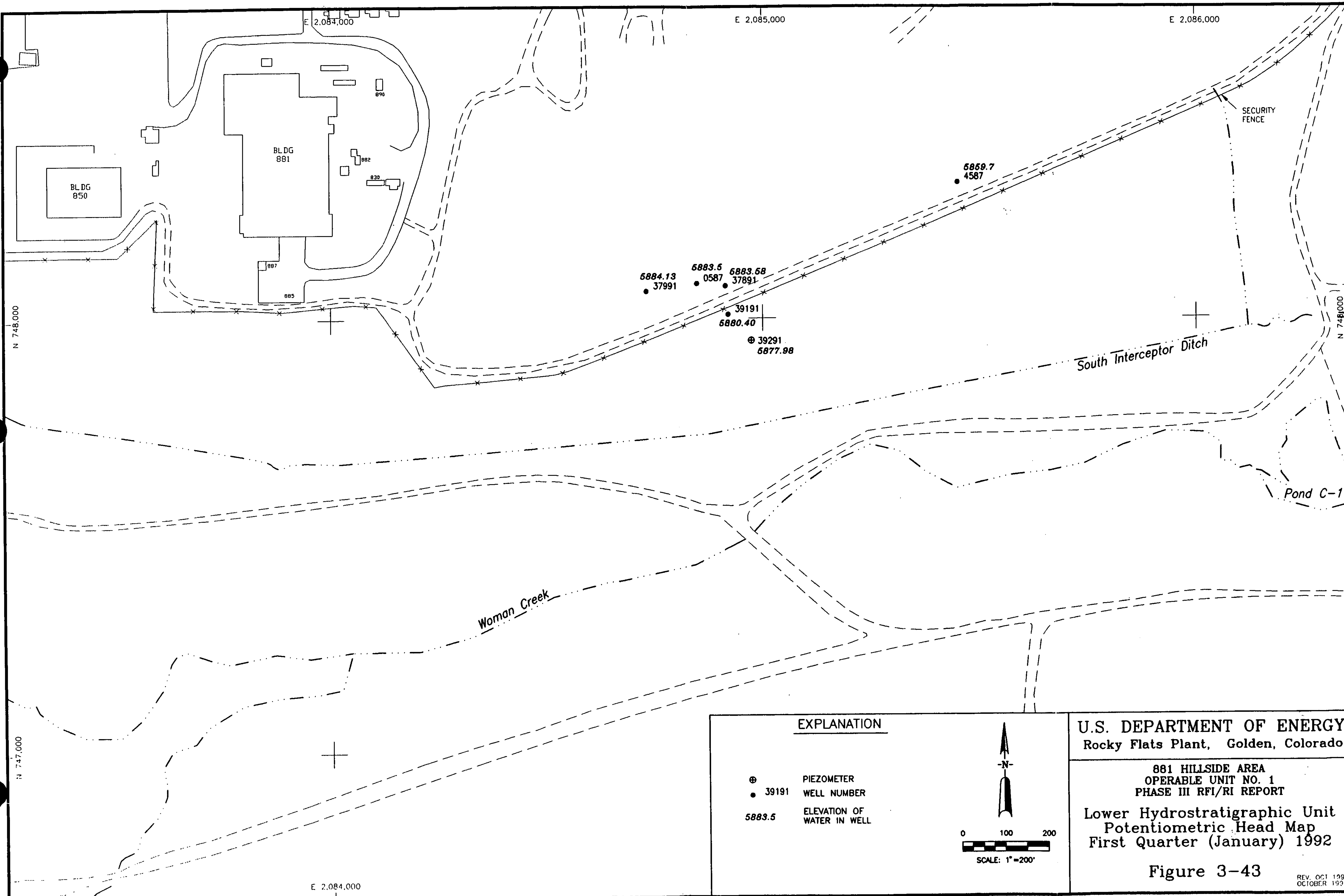
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Hydraulic Conductivities for Upper and Lower HSU Materials at OU1

Figure 3-42

REV. OCTOBER 1993
OCTOBER 1992

R74027.PJMB102193



EXPLANATION

⊕	PIEZOMETER
● 39191	WELL NUMBER
5883.5	ELEVATION OF WATER IN WELL

-N-

0 100 200

SCALE: 1"=200'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

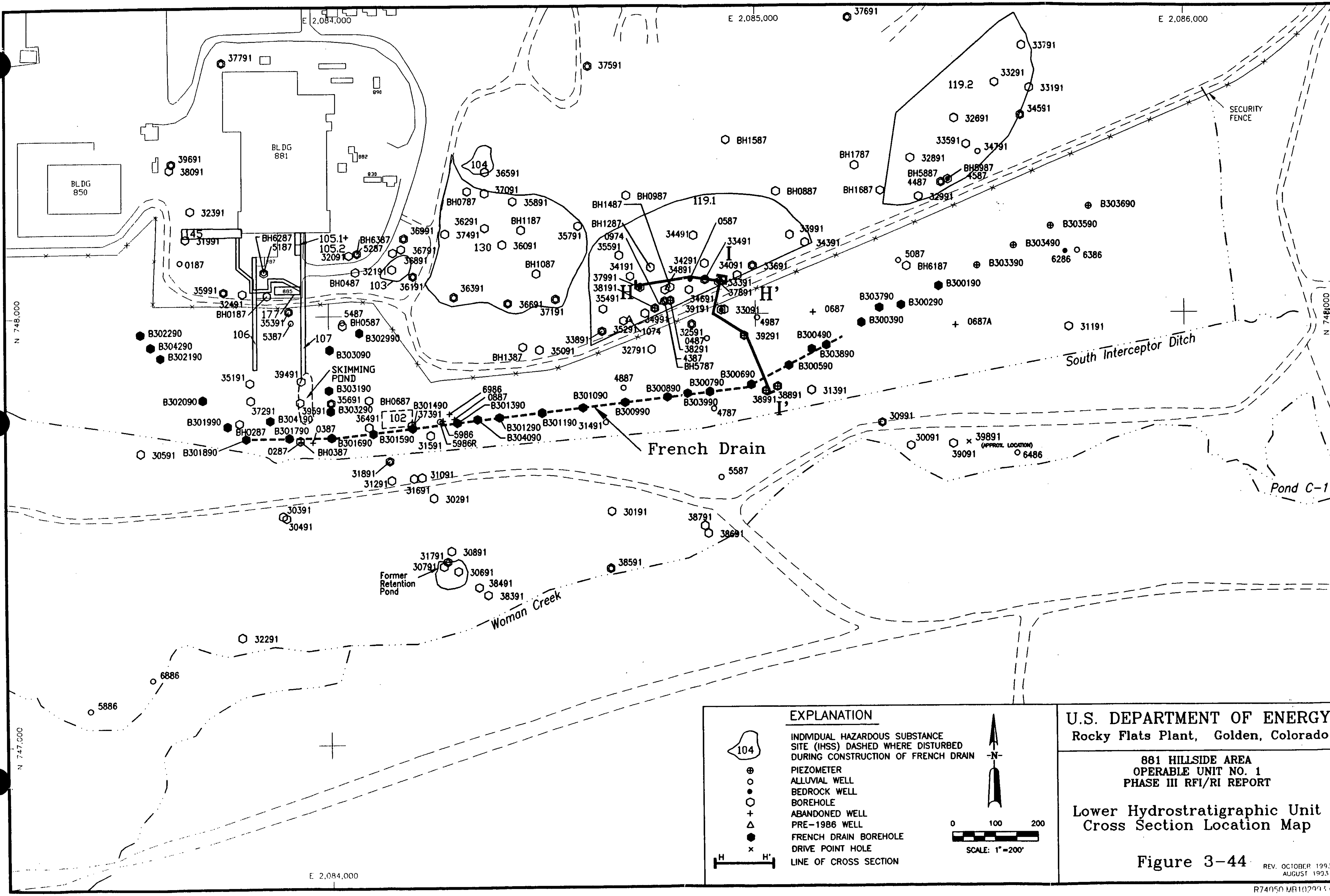
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Lower Hydrostratigraphic Unit
Potentiometric Head Map
First Quarter (January) 1992

Figure 3-43

REV. OCT 1993
OCTOBER 1992

R74004.MBpj-102893/200



EXPLANATION

- 104 — INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
- ⊕ PIEZOMETER
- ○ ALLUVIAL WELL
- ● BEDROCK WELL
- ⬡ BOREHOLE
- + ABANDONED WELL
- △ PRE-1986 WELL
- ⬢ FRENCH DRAIN BOREHOLE
- × DRIVE POINT HOLE
- H—H' LINE OF CROSS SECTION

-N-

0 100 200

SCALE: 1"=200'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

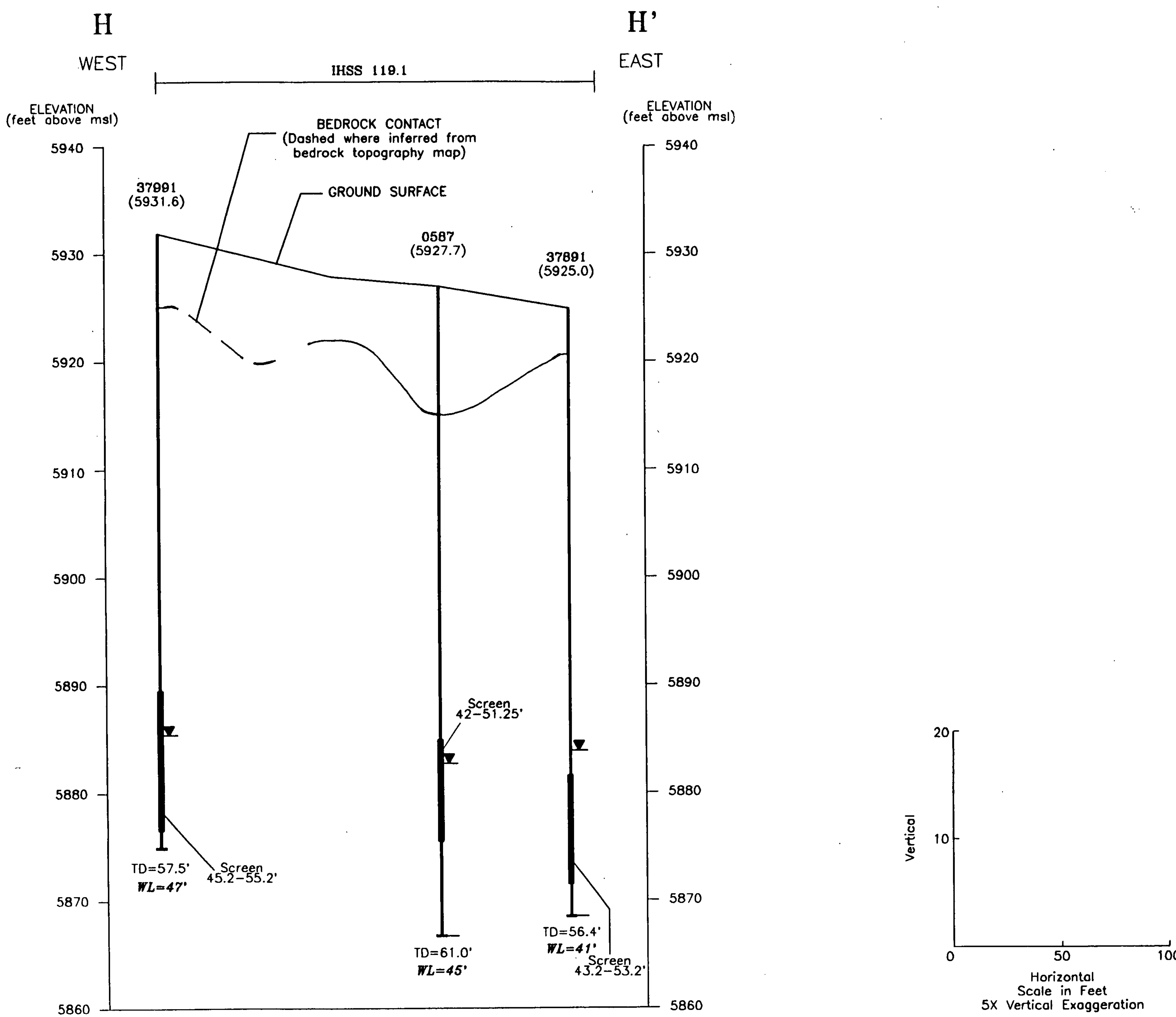
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

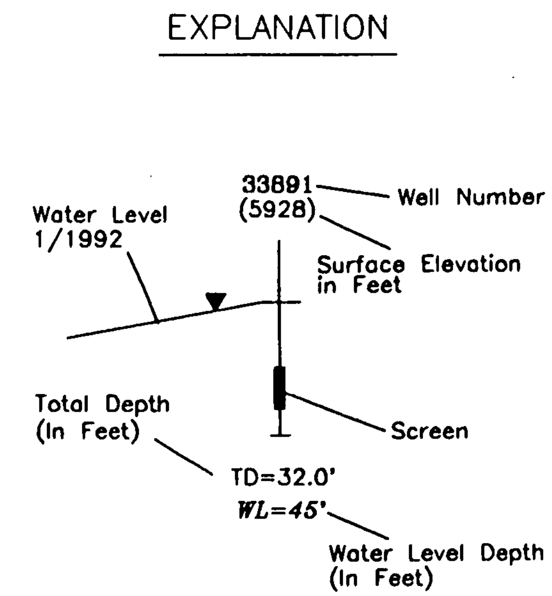
Lower Hydrostratigraphic Unit Cross Section Location Map

Figure 3-44

REV. OCTOBER 1993
AUGUST 1993

R74050 MR102993 (20)





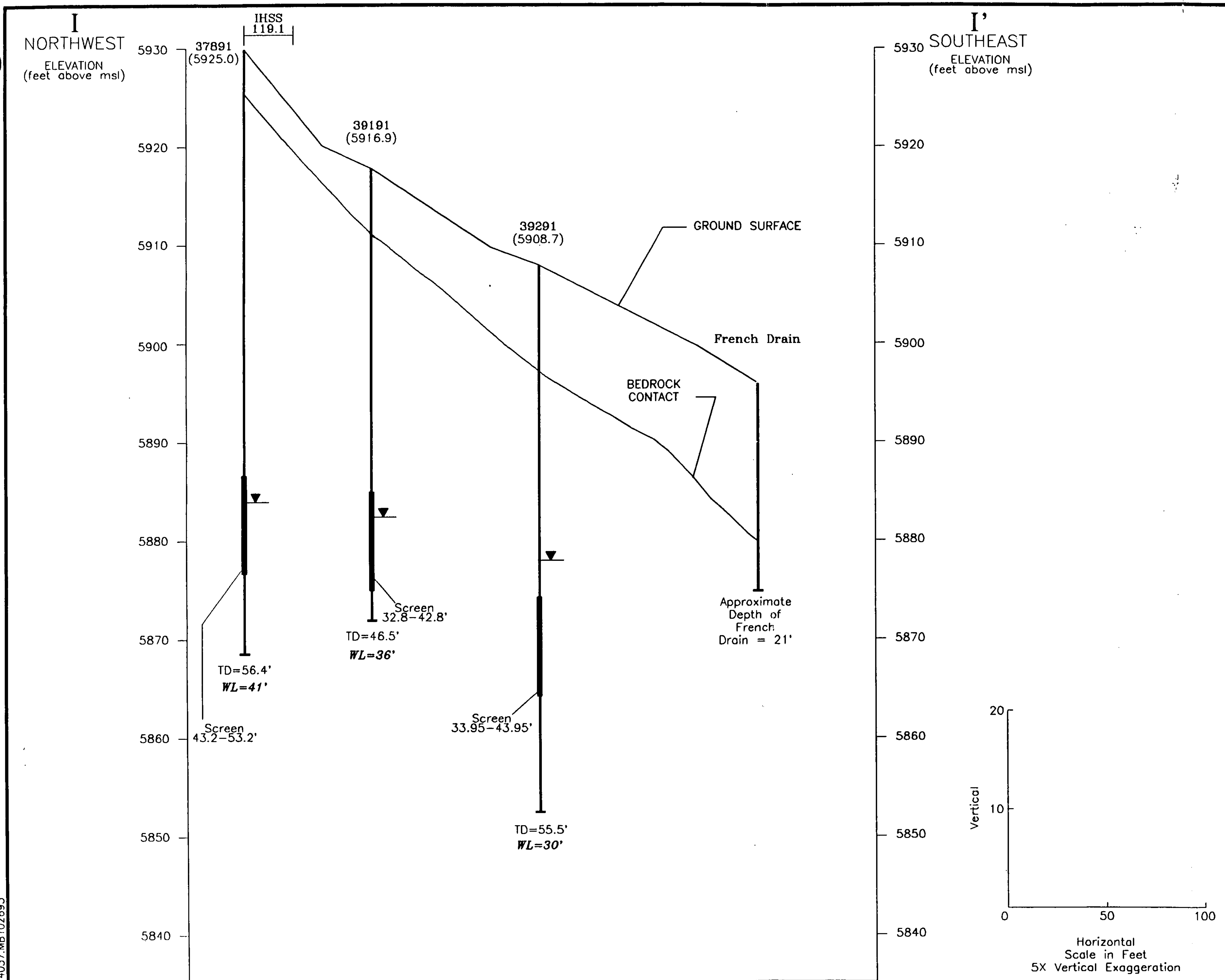
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Lower Hydrostratigraphic Unit
Cross Section H-H'
Figure 3-45

REV. OCTOBER 1993
OCTOBER 1992

R74036.MB102893



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

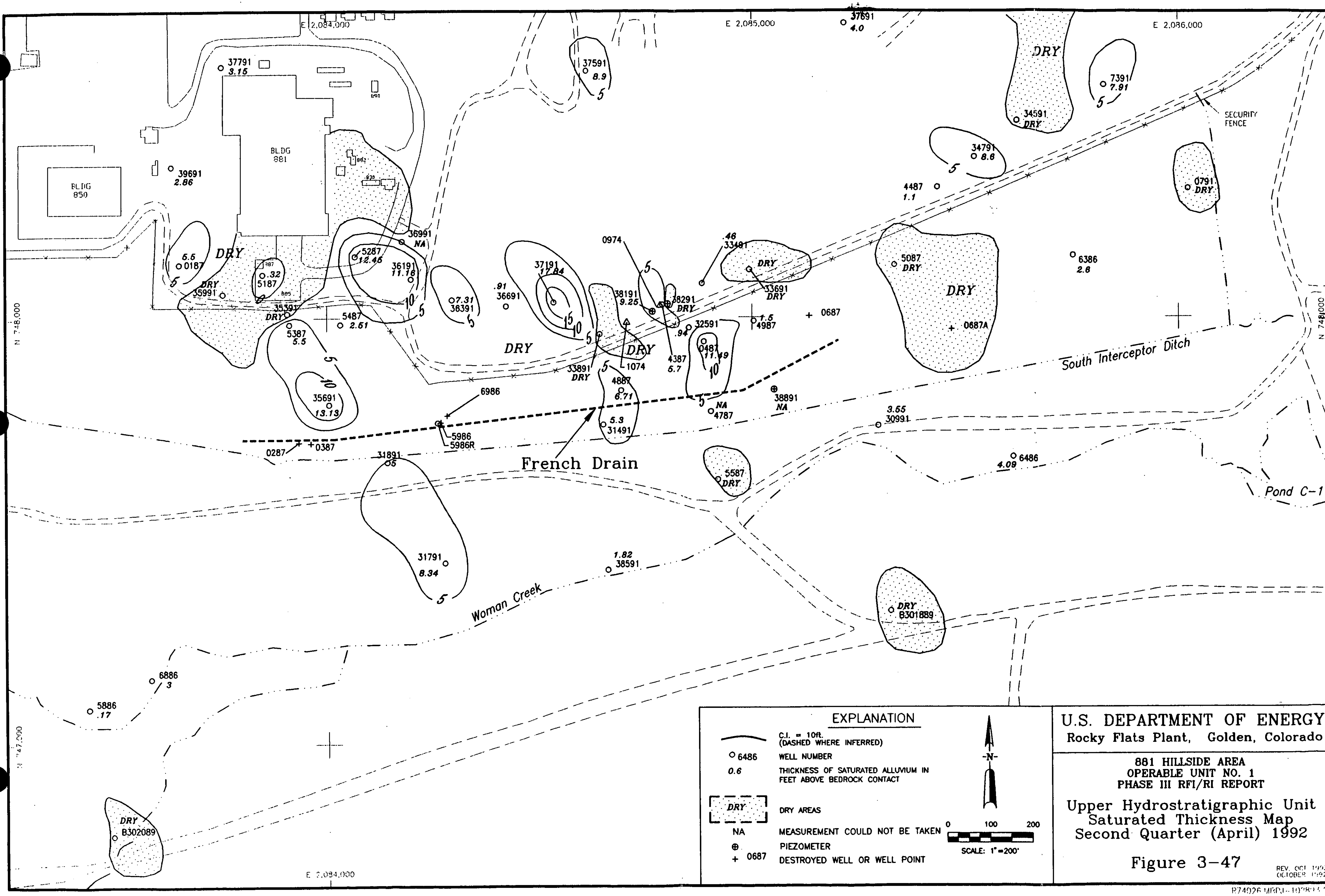
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Lower Hydrostratigraphic Unit
Cross Section I–I'

Figure 3–46

REV. OCTOBER 1993
OCTOBER 1992

R74037.MB102693



EXPLANATION

C.I. = 10ft. (DASHED WHERE INFERRED)

6486 WELL NUMBER

0.6 THICKNESS OF SATURATED ALLUVIUM IN FEET ABOVE BEDROCK CONTACT

DRY DRY AREAS

NA MEASUREMENT COULD NOT BE TAKEN

PIEZOMETER

\+ 0687 DESTROYED WELL OR WELL POINT

-N-

0 100 200

SCALE: 1" = 200'

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant, Golden, Colorado

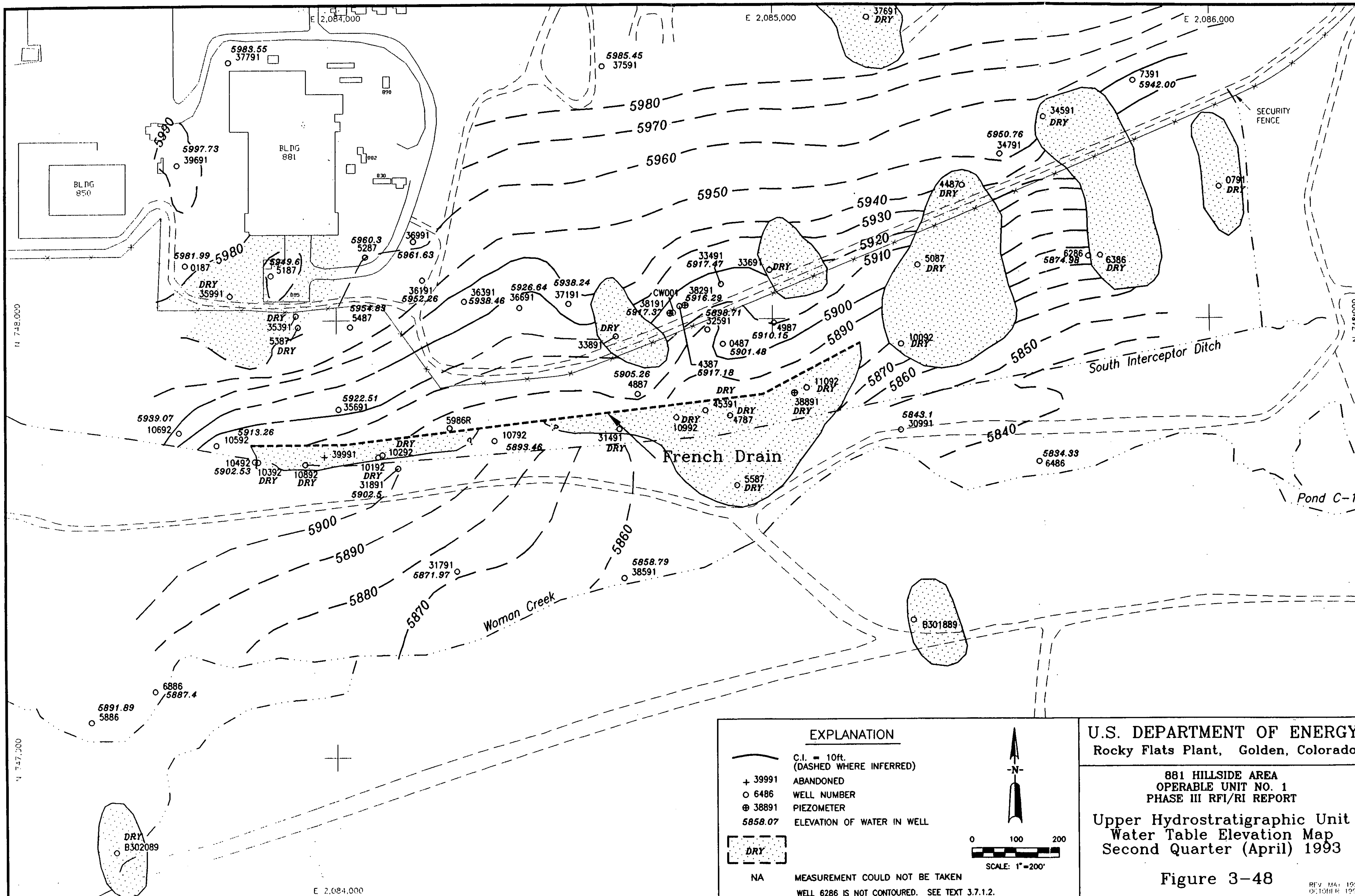
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Upper Hydrostratigraphic Unit
Saturated Thickness Map
Second Quarter (April) 1992

Figure 3-47

REV. OCT 1993
OCTOBER 1992

R74026 MBDJ-10/28/93 (200)



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

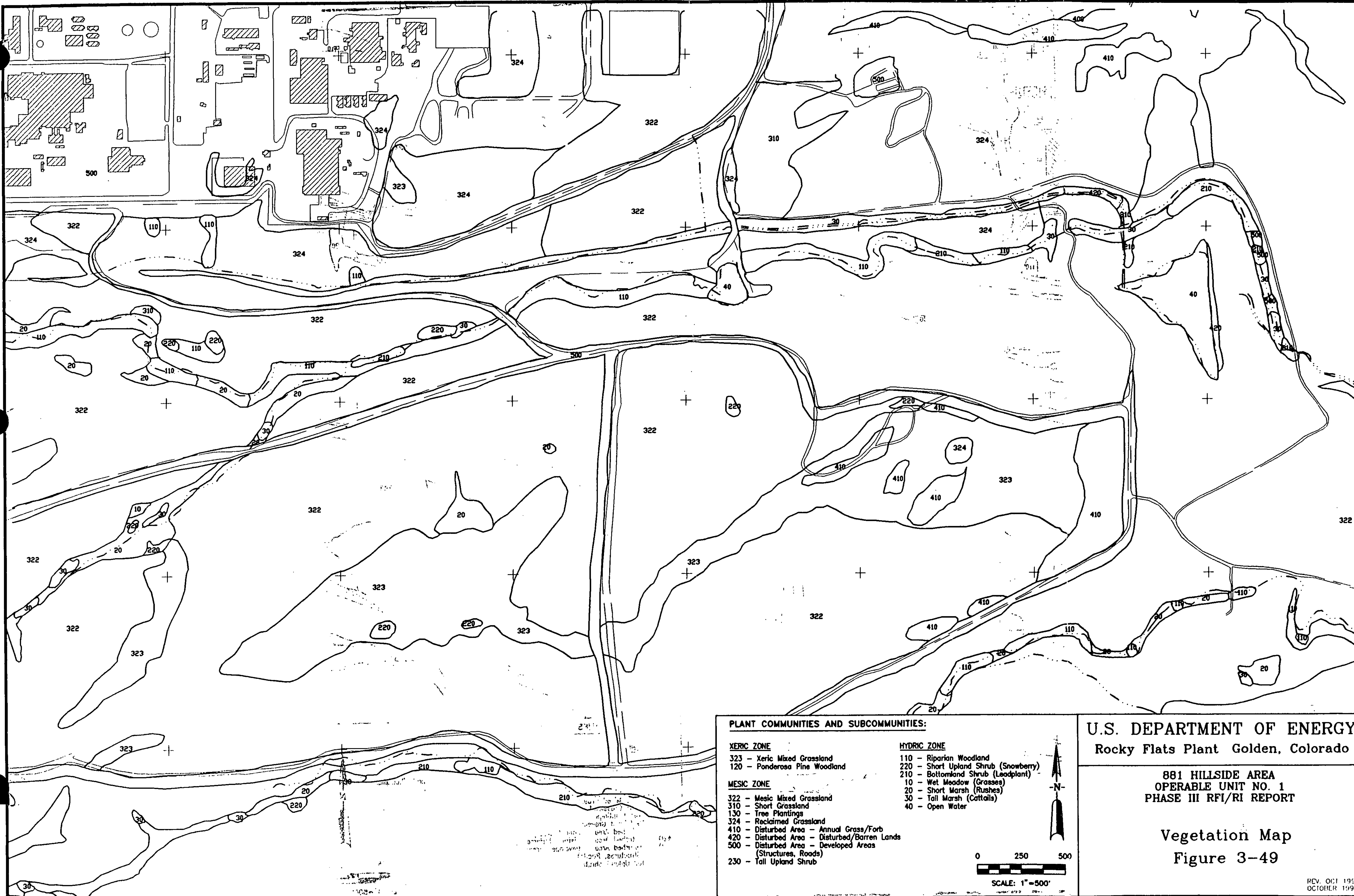
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Upper Hydrostratigraphic Unit
Water Table Elevation Map
Second Quarter (April) 1993

Figure 3-48

REV. MAY 1994
OCTOBER 1992

R74024.MBMBM-052494/200



PLANT COMMUNITIES AND SUBCOMMUNITIES:

XERIC ZONE

323 – Xeric Mixed Grassland
120 – Ponderosa Pine Woodland

MESIC ZONE

322 – Mesic Mixed Grassland
310 – Short Grassland
130 – Tree Plantings
324 – Reclaimed Grassland
410 – Disturbed Area – Annual Grass/Forb
420 – Disturbed Area – Disturbed/Barren Lands
500 – Disturbed Area – Developed Areas (Structures, Roads)
230 – Tall Upland Shrub

HYDRIC ZONE

110 – Riparian Woodland
220 – Short Upland Shrub (Snowberry)
210 – Bottomland Shrub (Leadplant)
10 – Wet Meadow (Grasses)
20 – Short Marsh (Rushes)
30 – Tall Marsh (Cattails)
40 – Open Water

-N-

0 250 500

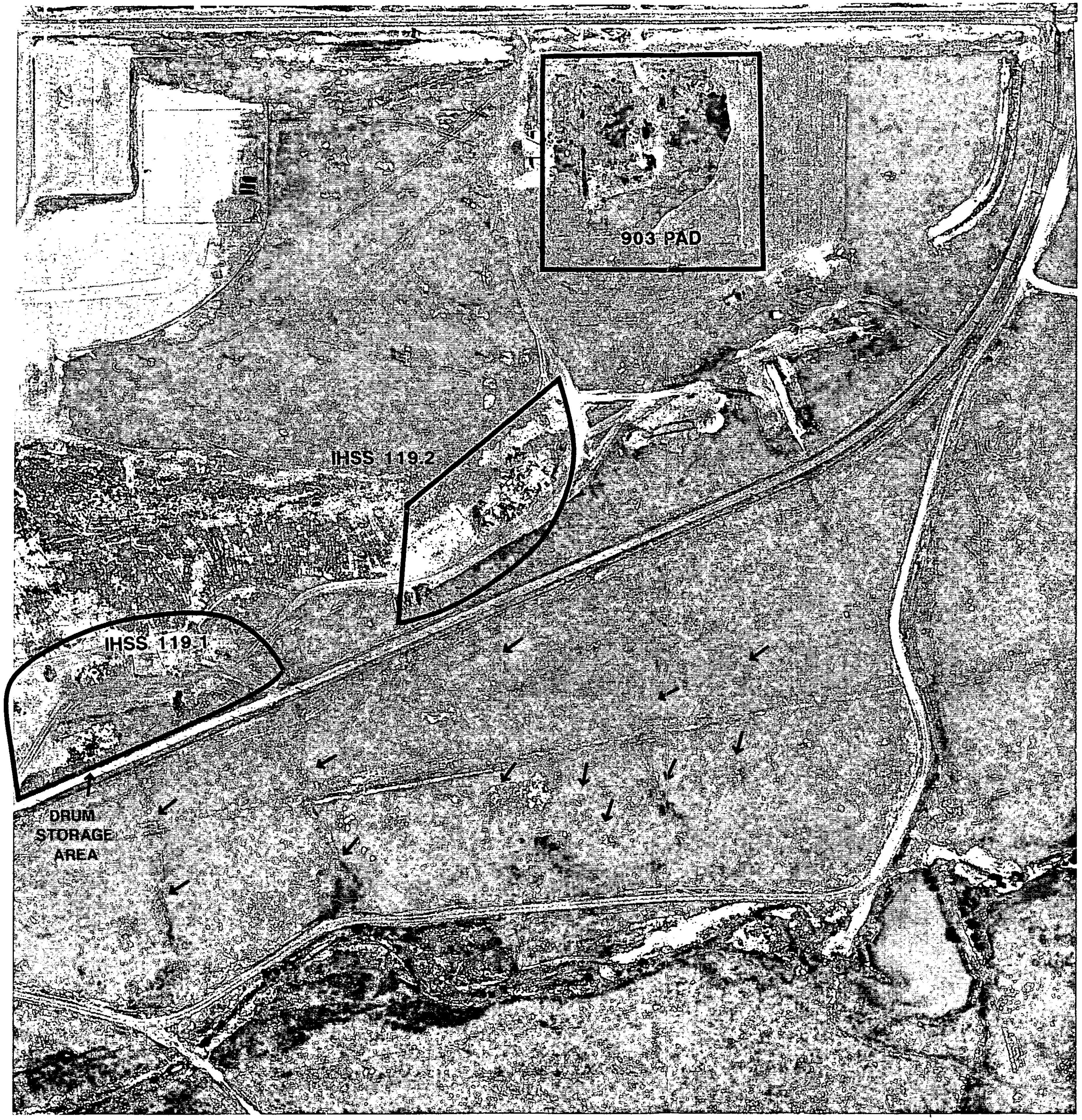
SCALE: 1" = 500'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Vegetation Map
Figure 3-49

REV. OCT 1993
OCTOBER 1992



EXPLANATION

104 INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS)

INDICATES SURFACE DRAINAGE THAT APPEARS TO BE COINCIDENT WITH POTENTIAL GROUNDWATER MIGRATION PATHWAYS

NOTE: Photo taken by Colorado Aerial Photo Service
SCALE: 1" = 200'; DATED: 5/24/69

-N-

0 100 200

SCALE: 1"=200'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Surface Expression of Potential Groundwater Migration Pathways

Figure 3-26

OCTOBER 1993

R74272.PJ-102193/200